1 Introduction

Of interest in this study is the sensitivity to lexical stress between good and poor readers in speech perception; and in particular, spoken word recognition of bisyllabic words. Spoken bisyllabic words like RECord[1] and reCORD, are segmentally the same - they have the same phonemes - but differ in their suprasegmental features such as pitch, amplitude and timing on the first and second syllables. The emphasis placed on the first (trochaic) or second (iambic) syllable of these words is referred to as lexical stress (Cutler, 2008; Soto Faraco, Sebastian Galles, & Cutler, 2001),which as a suprasegmental feature can be used in distinguishing between similar sounding words, and also between the word's grammatical classification. For example, the sentence "the *RECord* was lost, so I asked Mary to *reCORD* another copy" uses the word *record* as a Noun (RECord) and a Verb (reCORD) depending on its lexical stress location. This thesis examines the assumption that poor readers are too sensitive and attend too much to lexical stress in spoken word recognition.

1.1 Lexical stress

Lexical stress can be defined as the pattern of emphasis associated with a word's citation-form pronunciation (Slowiaczek, Soltano, & Bernstein, 2006). In the physical characteristics of the speech signal, the stressed syllable normally has longer duration, higher frequency (pitch) and higher amplitude (Lieberman, 1960). Of these three attributes of lexical stress, pitch is the most critical with amplitude a close second (Thiessen & Saffran, 2004). Lexical stress acts on syllables and its emphasis

[1] Capitalization denotes Lexical Stress

can be graded; that is those syllables that receive the greatest emphasis are designated primary stress and those with reduced stress are designated secondary or tertiary stress. In two syllable words, lexical stress on the first syllable is trochaically stressed, and lexical stress on the second syllable is iambically stressed.

1.2 Segmenting words from the speech stream

When we hear speech, we use a collection of means to segment the words from the speech stream. Speech is connected; there is not a pause after every word to indicate word offset or onset. However, there are various cues to word segmentation, which could be grouped into two principal classes: those that incorporate some “explicit mechanisms” such as stress and phonotactics; and the “serendipitous” word segmentation strategy, which relies on known words (Cutler, 1996). The *explicit mechanisms* include cues to rhythmic structure (Cutler & Norris, 1988), phonotactic constraints (McQueen, 1998), acoustic and allophonic cues (Church, 1987; Cutler, 1989), silent pauses (Gow & Gordon, 1995; Lehiste, 1972), vowel harmony (Suomi, McQueen, & Cutler, 1997; Vroomen, Tuomainen, & de Gelder, 1998), acoustic cues (Davis, Marslen Wilson, & Gaskell, 2002), and co-articulation (Fougeron & Keating, 1997; Johnson & Jusczyk, 2001; Mattys, 2004). The most important of these strategies are word stress patterns and phonotactics (more on this in the next section). In particular, listeners do use the stress pattern of words as a cue to word onset (Cutler, 1995; Cutler & Van Donselaar, 2001; Grosjean & Gee, 1987; Grosjean & Hirt, 1996); except there are two stress classifications referred to as metrical stress and lexical stress. Metrical stress is described briefly below. As this thesis focuses on lexical stress, it is important to be aware of the distinction between the two word stress segmentation approaches.

1.2.1 Metrical stress approach

Metrical stress is a conceptualization of stress based on the vowel quality in a syllable (Cutler & Norris, 1988; Fear, Cutler, & Butterfield, 1995; Slowiaczek et al., 2006). Strong syllables are those that contain full vowels. Weak syllables are those that contain reduced vowels, usually schwa /@/. For example, the word "motel" contains a strong vowel in the first syllable and a weak vowel in the second syllable. Cutler and Norris (1988) found that spotting a word in a nonsense word (e.g. "mint" in the nonword "mintayve") was more difficult if both syllables started with a full vowel. Participants would segment the nonword "mintayve" into two syllables "min" and "tayve", making the recognition or spotting of the word "mint" difficult. However, if the second syllable started with a reduced vowel (a schwa) then the recognition of a word was much easier. For example, it was much easier to spot the word "mint" in the nonword "mint@f", where @ indicates a reduced vowel. Another experiment that highlighted the use of stressed syllables is Cutler and Butterfield's (1992) examination of "slip of the ear"; a misperception of an utterance. For example, when an utterance (e.g., "conduct ascents uphill") that alternated in a strong-weak pattern was low pass filtered, the listeners reported hearing "the doctor sends the bill". The participants segmented the utterance at strong syllables. Cutler and Norris (Cutler, 1986, 1989; Cutler & Norris, 1988) proposed a metrical segmentation strategy, which suggests that English listeners preferred to segment speech streams using strong syllables, where the quality of the vowel in the syllable provides clues to word onset. For a comparison between metrical and lexical stress in word recognition, see Slowiaczek, Soltano and Bernstein (2006).

1.2.2 Lexical stress approach

Lexical stress can be used to excise a word from a speech stream. Evidence for lexical stress affecting word segmentation comes from a Thiessen and Saffron (2003) study. They habituated 9-month-old babies to an artificial language consisting of sentences with iambic disyllabic words “daPU#buGO#diTI#doBI”, and sentences consisting of trochaic disyllabic words “DApu#BUgo#DIti#DObi”. If infants excised words using the stress syllable as cue, they would select words like PU#bu from the iambic sentence, which is a part-word consisting of the last syllable of one word and first syllable of another word. Using the head turn paradigm protocol they tested participants on whole word and part-word perception. In the iambic trial, they found that participants preferred the part-word (PUbu), which consists of the strong iambic syllable PU in the word (daPU) and the weak syllable (bu) in the second word (buGO), rather than the word (daPU). In the trochaic case, they found that participants preferred the word (DApu) rather than (puBU) words. Their results suggest that participants use lexical stress to extract words from an artificial speech stream and they preferred words starting with lexical stress on the first syllable.

1.3 Developmental aspects

Thiessen and Saffron (2003) have shown that 9-month old children use lexical stress to find word onset in a speech stream. How does speech perception develop? It starts early! To assess if 3-day old infants could distinguish word boundaries, Christophe, Dupoux, Bertoncini and Mehler (1994) created two conditions by splicing a word contained in another word and by creating a new word from the offset syllable of one word and the onset syllable of a next word. For example, the French word 'mati' was either spliced from the word 'mathe***mati***cian' or was created as a combination of offset and onset syllables two words like 'cine***ma ti***tanesque'. These segments were presented to 40 three-day old infants using the habituation technique, where frequency of sucking decreases with the onset of habituation; and release from habituation is indicated with an increase in sucking frequency. They determined that infants could distinguish differences between items with (e.g. 'cine[***ma ti]***tanesque) and without (e.g., 'mathe[**mati]**cian') boundaries. One could almost say that infants are "bootstrapped" for language perception (Christophe et al., 1994), and for identifying the spoken word onset.

According to Aslin, Saffran, and Newport (1998), infants have the ability to discern every phonetic contrast used across human languages. Nevertheless, this ability appears to be short-lived. Werker and colleagues (Saffran, Werker, & Werner, 2006; Werker & Curtin, 2005; Werker & Desjardins, 1995) have noted that between 6-12 mths of age, infants can no longer discriminate non-native contrasts. Over that first year, they appear to reorganise their linguistic sensitivity to complement their native language. So that, after a year, the infant's speech sound discrimination begins to match that of the adult community. Maye, Werker and Gerken (2002) claim that it is somewhat counter-intuitive to characterise decline in performance as an indication of cognitive development, but these changes in perception reflect the focus of the infants' attention to acoustic dimensions that are relevant to their native language.

An interesting observation, it appears that word segmentation alternates between stress cues and phonotactic (distributional cues) at varying ages of the language learner. When infants are between 6-7 months (Echols, Crowhurst, & Childers, 1997; Jusczyk, Cutler, & Redanz, 1993), they use distributional cues, which are the likelihood that one syllable will follow another (see later section on phonotactics). This assertion is supported by Thiessen and Saffron (2003) study, where 9-month old babies preferred lexical stress cues, yet the younger 6-7 months old group preferred distributional cues. Syllables that consistently occur together in words have a higher distributional value, these syllables later to follow one another. However, when infants are between 8-9 months, they use lexical stress cues (Johnson & Jusczyk, 2001) to segment words from the speech stream. What is not evident is whether this alternation between stress and distributional processing is a normal developmental progression. It's been asserted by Wells, Pepe and Goulandris (2004) that as children age beyond 11-12 years, they tend to rely more on phonotactics (see experiment 2)

1.4 Lexical access

Since lexical stress is used to *segment* a word from a speech stream, does lexical stress also constrain lexical access? Various paradigms have been used to assess lexical stress, some of these include: recognising words that are mis-stressed (Cutler & Clifton, 1984; Slowiaczek, 1990), a gating task where lexical stress constrains lexical access (Lindfield, Wingfield, & Goodglass, 1999b; Wingfield, Goodglass, & Lindfield, 1997) as well as stress manipulation in cross-modal fragment-priming tasks (Cooper, Cutler, & Wales, 2002). These segmentation strategies are explained in the following sections.

1.4.1 Mis-stressed words

To emphasise the role of lexical stress, Cutler & Clifton (1984) found that incorrect lexical stress patterns interfered with word recognition. Shifting metrical stress without altering the vowel quality had a small effect on word recognition (Cutler & Clifton, 1984). However, mis-stressing words by shifting the lexical stress from the first syllable to the second, like INsert pronounced as inSERT, had no effect on word recognition (Small, Simon, & Goldberg, 1988). However, mis-stressing words to create a non-word, like pronouncing cheMIST for CHEMist, did inhibit recognition. Likewise Slowiaczek (1990) tested participants on tri-syllabic words like DIPlomat, which were recognised faster than incorrectly stressed words like dipLOmat in shadowing and lexical decision tasks.

To further test sensitivity to lexical stress patterns, Wood (2006) devised a novel paradigm where she interchanged the stressed and unstressed syllable in nouns. For example, the lexical stress pattern in “SOfa” was inverted to “soFA” with the stress on the second syllable. The word was then mispronounced and the participant had to point to a picture of a sofa if they interpreted the word correctly. Her results showed that 5-7 year old children had difficulty with the inverted stress pattern suggesting relatively greater dependence on stress information.

1.4.2 Lexical stress constrains access

Cutler (1986) argued that suprasegmental information is not used in lexical access. She used minimal pairs such as FORbear and forBEAR in a cross modal associated priming task. In this case, the target words *ancestor* and *tolerate* were associated with both primes FORbear and forBEAR when the inter stimulus interval (ISI) between prime and target was short. However, when the ISI between the prime and target was increased, each item only primed one associated target; that is, FORbear primed *ancestor* and forBEAR primed *tolerate*. From this result, Cutler concluded that lexical stress does not constrain lexical access, but that lexical stress is applied post lexically to disambiguate the items after they were accessed from the lexicon. Not everyone concurred with Cutler's (1986) earlier view (it has since changed) and some (Cooper et al., 2002; Lindfield, Wingfield, & Goodglass, 1999a; Norris, Cutler, McQueen, & Butterfield, 2006; van Donselaar, Koster, & Cutler, 2005) argued that since lexical stress is used to *segment* words from the speech stream, the information is also used to access the lexicon.

The results from Lindfield, Wingfield and Goodglass (1999b) support the claim that lexical stress does constrain word access. Using a gating task, they created three conditions using disyllabic words (e.g. ballet and dolphin) and trisyllabic words (e.g. celery, radio and kangaroo). The first condition presented the word in 50 ms time slices. The second condition presented the word in 50 ms time slices but filled the remaining duration with white noise so that the listener would have some suprasegmental information available but not the number of syllables nor their relative stress. The third condition presented the word in 50 ms time slices, but the remainder of the word was filtered, which allowed the listener to hear syllables and suprasegmental patterns without revealing the word itself. Their results showed that words in the third condition were recognised with less segmented onsets, suggesting that suprasegmental information is included in the lexical trace for word access.

Norris, Cutler, McQueen and Butterfield (2006) reported nine cross modal priming experiments comparing identity and associated auditory primes. They tested priming when the prime was part of a sentence or a single word prime was presented. Their results showed semantic and identity priming, but not associative priming. They posited that conceptual representations in associated priming do not activate phonological processes and so the cross-modal “forBEAR” experiment by Cutler (1986) may not have tapped into the processing level at which suprasegmental constraints play a role in lexical access. Van Donselaar et. al. (2005) used cross-modal priming experiments where the visual target was a trisyllabic visual word (e.g. OCtopus and okTOber) and the spoken prime was a word truncated after the first two syllables creating a trochaic (e.g. OCto) or iambic (e.g. okTO) fragment. Participants had to make lexical decisions of multisyllabic target non-words or words presented visually that either matched or mismatched the spoken prime fragment. Van Donselaar et. al. found that suprasegmental information does constrain lexical access. With regards to the suggestion that lexical stress is applied post lexically in the earlier “forBEAR“ experiment (Cutler, 1986), they explained it thus, “On the other hand, other recent findings cast doubt on the comparability of at least the earlier associative priming result with the more recent fragment-priming data” (van Donselaar et al., 2005, p 254).

The processing of suprasegmental features appears to be constrained by language usage. For example, Spanish and Dutch listeners utilise suprasegmental features (Soto Faraco et al., 2001; van Donselaar et al., 2005) in spoken word recognition, whereas proficient English users do not rely much on suprasegmental features in spoken word recognition. They prefer to process items at the segmental level and access the lexicon using segmental information first, then apply suprasegmental features post-lexically as implied by Norris, Cutler, McQueen and Butterfield (2006) Cooper, Cutler and Wales (2002) also tested spoken word recognition in a cross-modal segment completion task, and found that English users can exploit suprasegmental features in word recognition.

Given these later findings above, it appears therefore that lexical stress does constrain lexical access; it disambiguates words, helps in excising words from the speech stream, and assists in defining grammatical class.

1.5 Reading

There has been extensive research over the last 10 years in an attempt to identify the cognitive processes that underlie literacy acquisition (Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). To-date, the two most stable factors that predict reading ability are phonemic awareness (Wagner, Balthazor, Hurley, Morgan, & et al., 1987; Wagner & Torgesen, 1987) and naming speed (rapid automatised naming, Wolf & Bowers, 1999). With this focus on phonemic awareness and rapid automatised naming, there has been comparatively little research on suprasegmental features (Wade-Woolley & Wood, 2006), such as rhythm. Whereas phonemic awareness is based on the understanding that language can be broken down into smaller units of sound, a phoneme that can be manipulated, rhythm refers to a relationship between the sounds of these units (Shankweiler & Fowler, 2004).

1.5.1 Phonemic awareness

Phonemic awareness is reflected in the conscious identification and manipulation of phonemes (Yopp, 1988). This includes the ability to combine and voice two or more phonemes (blends), identify phoneme strings that have a common sound (rhymes), remove a phoneme from a string and voice the result (sound deletions), identify the number of phonemes in a string (phoneme counting), and voice each successive phoneme in a string (segmentation). One of the critical reasons given for this connection between phonemic awareness and reading is that phonemic awareness supports the alphabetic principle (Byrne, 1996). Readers make the connection between the phonemes and the written symbols (graphemes) that represent the sounds (Ehri, 1991; Griffiths & Snowling, 2001; Windfuhr & Snowling, 2001). Why is it that some children have difficulty achieving phonemic awareness?

One of the answers lies in how children implicitly perceive phonemes. “Perception is said to be categorical when discrimination is better for stimuli belonging to different categories than for stimuli belonging to the same category, even though physical differences are the same in both the cases” (Serniclaes, Ventura, Morais, & Regine, 2005). This suggests that poor readers may remain sensitive to allophones, and have difficulty categorising allophones as a single phoneme. For example, the phoneme ‘p’ in the word ‘spot’ and ‘plot’ may be discerned as two different phonemes by the poor reader; and it takes time to regularise the two distinct sounds of /p/ to one phoneme /p/. As such, speech perception has obvious implications for the acquisition of alphabetic writing (Serniclaes, Van Heghe, Mousty, Carre, & Sprenger-Charolles, 2004). Hence, for the poor reader, phonemes are less well defined. Consequently, in the absence of clearly defined phonemes, grapheme-to-phoneme correspondence will be at best 'fuzzy' for the poor reader.

Given the shortcoming with grapheme-to-phoneme correspondences, does not mean that poor readers will never adequately perceive phonemes. Recent advances in reading training suggests that explicit training in phonetic contrast is achievable (Perfors & Dunbar, 2010). Although second language learning is not the focus of this research, we can also see evidence for acquiring phonemic awareness in the context of second language acquisition. Japanese learners of English have difficulty with the phonetic contrasts /r/ - /l/. Researchers (Bradlow, Akahane-Yamada, Pisoni, & Tohkura, 1999; Perfors & Dunbar, 2010) have shown that this difficulty can be reduced through the explicit teaching of phonetic contrasts. Moreover, as Bradlow et. al report, these phonetic contrast learning methods provide an optimistic outlook for the application of such procedures for a wide range of "special populations": Presumably, this includes poor readers.

1.5.2 RAN

The second of these stable predictors of reading is rapid automatised naming (RAN, Denckla & Rudel, 1976). Participants are asked to name items presented in a randomised serial array as quickly as possible (Katzir et al., 2006; Wolf & Obregon, 1997). These named items are normally letters, digits, colours or pictures of familiar objects. Poor readers take longer to name items when compared to their normal achieving peers and may also suffer a “double deficit”; that is, they lack phonemic awareness and do poorly on the RAN task (Wagner & Torgesen, 1987; Wolf & Bowers, 1999). Some have argued that the lack of naming speed found in poor readers is largely a phonemic deficit issue – they need to know the sound; and that phonemic awareness and RAN are tightly related (Bowey, McGuigan, & Ruschena, 2005) because naming letters requires some phonemic knowledge.

1.5.3 Suprasegmental sensitivity

Although phonemic awareness and the RAN task are good indicators of reading proficiency, the reasons why children fail to acquire phonological awareness despite explicit tuition are less well understood. A decade ago, Ramus (2001) suggested that some of the answers may lie in exploring the sensitivity to processing suprasegmental features, a domain that is largely ignored by reading researchers. Suprasegmental sensitivity has been related to speech stream processing (Wood & Terrell, 1998), lexical stress (Wood, 2006), and reading aloud (Gutierrez-Palma, Raya-Garcia, & Palma-Reyes, 2009).

Wood and Terrell (1998) analysed relationships amongst prosodic sensitivity, reading difficulty and spoken word recognitions in a sentence-matching task . They low-pass filtered six syllable sentences so that only the intonation pattern remained and tested the low-passed filtered sentence against the original and against one that was different. They found that poor readers were significantly worse at performing the task than aged-matched controls. In further analysis of the data in 2006, Wood, after controlling for vocabulary, age and prosodic sensitivity still found significant differences in phonological awareness scores. She concluded that prosodic sensitivity underpins phonological awareness skills.

1.5.4 Lexical stress and rhythm

If poor readers had difficulty with six syllable sentences that were low pass filtered, would they be sensitive to the rhythm of the language which appears to assist in reading (Gutierrez-Palma & Reyes, 2007)? In the 1940's, Pike (1945) and James (1940) pointed out that there is a difference in the rhythm of languages such as English and Dutch, and languages like Spanish and Italian. Germanic languages like English, Afrikaans, Dutch and Slavonic language are stress-timed languages; Romance languages like Italian and Spanish are syllable-timed. There is a third category: mora-timed (Ladefoged, 1975) for languages such as Japanese and Tamil.

Cummins and Port (1998) have hypothesised a p-centre, which is a point that marks the temporal mid-point or centre point of a stressed syllable; it is the point in the syllable with the most energy as reflected by the peak amplitude. Rhythm is measured from p-centre to p-centre. In stress-timed languages like English the temporal difference between p-centres is almost constant (Wood, 2006). For those who are sensitive to speech rhythm, lexical stress becomes a "perceptually reliable rhythmic cue" (Mattys, 1997a) for attentional processes where attention “bounces” from one stressed syllable to the next in online sentence processing.

The idea that language has rhythm is central to explaining how infants first acquire spoken language. Evidence that infants use rhythm when learning their first spoken language was provided by Mehler, Dupoux, Nazzi and Dehaene-Lambertz

(1996). Using a habituation technique, they found that French newborns could distinguish the rhythm in filtered speech between English and Japanese, but not between English and Dutch (Nazzi, Bertoncini, & Mehler, 1998), which is evidence that supports the rhythmic similarity hypothesis; i.e., English and Dutch are both stress-timed languages with the same rhythm. This suggests that infants' perception of rhythmic classes play a significant role in the acquisition of language (Ramus, Nespor, & Mehler, 1999). Following on from the newborns perception of their first language, Goswami, Thomson, Richardson and Scott (2002) found that the development of phonemic awareness is related to sensitivity in rhythmic perception in sentence processing.

Turning now to a role for speech rhythm in reading, Gutierrez-Palma and Reyes (2007), using the "stress deafness" protocol devised by Dupoux and colleagues (Dupoux, Peperkamp, & Sebastion-Galles, 2001; Dupoux, Sebastian-Galles, Navarrete, & Peperkamp, 2008), found relationships between lexical stress sensitivity and reading. In this protocol, a 7-8 year old participant is habituated to two nonwords that differ on contrastive stress (eg. /mIpa / /mipA/)[2] or by a single phoneme (/kupi/ v /kuti/). Each non-word corresponds to a letter on a keyboard. For example, the non-word /kupi/ matches the letter 'L', and the non-word /kuti/ match the letter 'K'. During the test phase, the participant hears two, three or four non-word combinations (eg. kupi, kuti, kupi and kuti) and is required to respond by typing a sequence of letters that correspond to the sound sequence. Their results showed that performance on phoneme contrast sequences predicted word reading. In

[2] Capitalization denote Lexical Stress

addition, performance on stress contrast sequences predicted non-word reading. They proffered the idea that lexical stress sensitivity may be a factor related to reading fluency. Their results also showed that stress sensitivity (scored in two non-word sequences) predicted stress assignment and that knowledge of (lexical) stress rules predicted both word and non-word reading. What this study shows is that lexical stress sensitivity assists in learning stress rules, and that knowledge of stress rules is relevant for reading.

Furthermore stress sensitivity assists with the identification of phonemes, as it is easier when the phoneme appears in a stressed syllable (Chiat, 1983). The listener may use stressed syllables for lexical access. Hence, all other things being equal, words with lexical stress on the first syllable would take less time to recognise than words with stress on the second syllable. And, since a high proportion of English disyllabic nouns have trochaic stress patterns (Kelly & Bock, 1988), a disyllabic noun "RECord" would be recognised faster than the verb "reCORD".

We have seen how stress sensitivity may influence reading by mature, literate readers and how stress sensitivity contributes to reading proficiency (Wood, 2006). What is not clear, is why poor readers have difficulty with stress sensitivity (Wood & Terrell, 1998). One possible explanation is that poor readers attend too much to suprasegmental information and some of this information may even be irrelevant in their linguistic environment (Serniclaes, Van Heghe, Mousty, Carre et al., 2004). In some of the experiments reported in this thesis, processing lexical stress information is irrelevant to the task (e.g. Experiment 6). Yet, poor readers may still use this irrelevant information in spoken word recognition? The experiments in this thesis investigate “stress sensitivity” between good and poor readers as they process spoken disyllabic words with trochaic and iambic stress patterns.

1.6 Factors affecting spoken word recognition

Once the word has been excised from speech stream, factors such as phonotactics, word frequency, neighbourhood density and typicality influence the speed with which the words are recognised. Each of these factors is briefly described below.

1.6.1 Phonotactics

Words with initial stressed syllable are easier to excise from the speech stream (Norris, McQueen, & Cutler, 1995). This raises the issue of how words are recognised that do not have word-initial stress. For example, how is an iambic word like “reCORD” recognised in the speech stream? To perceive iambic words, the word recognition processes must rely on other means such as the dependence upon the knowledge of language sounds (phonemes) and the occurrence of sound sequences (Vitevitch, Luce, Pisoni, & Auer, 1999). Morgan (1996a) holds that adult listeners use phonotactics for word recognition and they rely less on lexical stress to assist with word recognition. For example, an English listener or reader would know that “Breznev” is not an English word because some of the sounds and sound sequences are alien to the English listener. Infants initially rely strongly on prosodic information that is available in the speech signal, but later transit to using phonotactics (Mattys, Jusczyk, Luce, & Morgan, 1999). The transition from a prosodic strategy to a phonotactics strategy suggests a developmental progression. Some readers may have difficulty transitioning to phonotactics. Since phonotactics rely on the distributional properties of segments. Poor readers who have fuzzy representations of segments will have difficulty computing phonotactics and there is evidence that some poor readers rely more on prosodic factors for word recognition (Mattys, White and Melhorn, 2005).

1.6.2 Frequency

One of the key features of word recognition is frequency; word frequency (Kucera & Francis, 1967) has been described as the most potent and salient factor facilitating recognition (Connine, 2004; Gordon, 1983; Kinsbourne & Evens, 1970; Whaley, 1978). Words with high frequency are recognised more easily as reflected in faster response times and greater accuracy than low-frequency words. Dahan, Magnuson, and Tanenhaus (2001) suggests that frequency effects reflect the earliest moments of lexical access, and ruled out a late-acting, decision-bias locus for frequency. In which case, frequency effects directly reflect lexical access.

Murray and Forster (2004) list other factors that influence word recognition, “concreteness, length, regularity (words that are typical) and consistency, homophony, number of meanings, neighbourhood density, and so forth.”(p.721), but these effects tend to be restricted to low frequency words. It has been known for a while that typical examples of superordinate concepts are categorised more rapidly (Rosch, 1975). As mentioned before, English is a stress-timed language and most nouns have a typical trochaic stress pattern, whereas verbs have a less typical iambic stress pattern (Kelly, 1992; Kelly, Morris, & Verrekia, 1998; Sereno & Jongman, 1990). Kelly and Bock (1988) analysed 3000 nouns and 1000 disyllabic verbs and found that 94% of nouns had stress on the first syllable, whereas 69% of verbs had second syllable stress. Given that trochaic words are recognised better than iambic words (Mattys & Samuel, 2000; Mattys, 2000), one expects trochaic nouns, which is typical in its class, to be better recognised than iambic nouns. Research suggests that typicality does affect word recognition for low frequency words (Colombo, 1992); that is low frequency typical words are recognised faster and have fewer errors than low frequency atypical words (Seidenberg, Waters, Barnes, & Tanenhaus, 1984). This means that low-frequency iambic verbs, which are typical in their grammatical class, will be recognised faster than low-frequency trochaic verbs suggesting an interaction between frequency and typicality. According to Murray and Forster (2004), low-frequency words that are typical in their grammatical class are generally recognised faster than words that are atypical, but this typicality effect only occurs for low-frequency words and not for high frequency words (Arciuli & Cupples, 2003, 2004).

Seidenberg, Waters, Barnes and Tanenhaus (1984) found an interaction where low-frequency words showed differences between typical and atypical items. Colombo (1992) investigated how Italian listeners processed regular and irregular Italian polysyllabic words in a naming task and lexical decision task. In Italian, most words are stressed on the penultimate syllable, which is considered typical. Approximately 30% of Italian words have stress on the antepenultimate syllable, which are considered irregular or atypical. Colombo's stimulus items consisted of high and low frequency typical and atypical nouns or adjectives. Her results showed an interaction between typicality and frequency for participants only, which showed high variability among items, suggesting that other word recognition factors were not adequately controlled. One of these factors could have been neighbourhood density.

1.6.3 Neighbourhood Density

The number of neighbours a word has also affects word recognition times; that is, words with many phonological neighbours slows down word recognition (Ziegler, Muneaux, & Grainger, 2003). Neighbourhood size is defined as the number of similar sounding words that can be created by the addition, subtraction, or replacement of a phoneme in a given word (Coltheart, Besner, Jonasson, & Davelaar, 1979). For example, the word /swim/ has many neighbours. When the second phoneme is replaced, it spells /slim/ and /skim/, if the third phoneme is replaced it spells /swum/ and /swam/, etc. Using the Cohort Model for word recognition (Marslen-Wilson, 1984), as information becomes available /s/, /sw/, /swi/, /swim/, each segment elicits words with similar phonemes, which eventually needs to be suppressed to reveal the target word. So, the more words that are similar or in the neighbourhood of the target word, the more words need to be suppressed and the longer it takes to recognise the target word.

The frequency of the similar sounding words also affects the word recognition process. High-frequency words with low frequency neighbours are easy to recognise due to less interference from partially activated neighbours. Hence, a low-frequency word with high-frequency neighbours is more difficult to recognise (Andrews, 1992; Goldinger, 1996; Goldinger, Luce, & Pisoni, 1989; Vitevitch & Luce, 1998).

1.7 Spoken word recognition

This section briefly describes the key phases involved in spoken word recognition when identifying a sound as a word. Dahan and Magnuson (2006) listed the phases of spoken word recognition to comprehension as a mapping between "acoustic onto phonetic categories, phonetic categories onto words in memory, words onto phrases and syntactic structure, and words and syntax onto semantics, etc."(p.249). Frauenfelder and Tyler (1987) define the phases from hearing the sound to lexical access : 1) the initial contact, where the listener processes the sound wave and generates contact acoustic/phonetic representations; 2) activation is when the contact representations match some lexical entries; 3) selection is when there has been sufficient activation and an item is selected; 4) word recognition is when the selection is deemed a word and part of the lexicon; and 5) lexical access is when the stored knowledge of the selected word is made available.

The phase that is of interest in this research is the acoustic-phonetic (suprasegmental/segmental) phase and particularly what strategies poor and good readers use during this phase in spoken word recognition. When processing the acoustic/phonetic information, McQueen(2005) asserts that there are two pre-lexical processes operating in parallel: "one extracting segmental structure from the signal and the one extracting suprasegmental structure"(p. 229). If poor readers are more sensitive to suprasegmental information than good readers (Cutler, 2008) are, one could extrapolate that poor readers are more likely to process suprasegmental features than good readers. Moreover, if some items can be categorised within a specific task based on their suprasegmental features alone, that is, utilising pre-lexical processes only, then word frequency should have no influence on the response if lexical information is not necessary in order to perform that specific task. Some of the experiments that follow will address the issue of pre-lexical processing by attempting to elicit information directly from a pre-lexical stage. The proof that pre-lexical processing has occurred is evidenced by the lack of any frequency effects, because the assumption is that words are accessed from the lexicon in frequency order.

Serniclaes, Sprenger Charolles, Carre, and Demonet (2001) tested children on their ability to discriminate native and non-native phonetic contrasts. They found that children with a diagnosis of dyslexia were more accurate at discriminating within-category contrasts within a phonemic boundary (eg. allophones), than between-category contrasts when compared to their normal achieving peers. Allophones are the phonetic variants of each phoneme; that is, a phoneme may be realized by more than one speech sound and the selection of each variant is usually conditioned by the phonetic environment of the phoneme (e.g. the /p/ sound differs in /spot/ or /pot/. Alternatively, one could argue that a phoneme is a set of allophones. This suggests that children with a dyslexic diagnosis may have a heightened sensitivity to the suprasegmental features in spoken language. This inference is supported by Cutler (2008), who suggested that the more proficient English readers are, the less they rely on suprasegmental features compared to less proficient user of English; rather, they focus on the segmental features of spoken words. This is not to say that proficient English readers cannot explicitly process suprasegmental features, as there are instances when even proficient English readers have to attend to the suprasegmental features of the words when they are explicitly required to distinguish between minimal pairs (eg. RECord, reCORD).

As inferred, poor readers may retain some of this sensitivity to process phonetic contrasts. This thesis, therefore, examines the assumption that poor readers are too sensitive to and attend too much to lexical stress in spoken word recognition. Secondly, this thesis examines the differences between, adults, good reader and poor readers when processing lexical stress in spoken word recognition.

1.8 Summary and Experiment Outlines

The above provides an overview of the key factors that influence word recognition and how they relate to reading ability. Lexical stress affects reading ability and the speed with which words are recognised. The goal of this thesis is to assess the relationship between reading ability and the sensitivity to lexical stress. This goal is explored in six experiments.

Experiment one uses two types of auditory lexical decision task, "yes/no" and "go/nogo", to identify which provides the more sensitive means of assessing sensitivity for spoken word recognition of trochaic and iambic disyllabic words. This first experiment involved adults with a view to use the same procedure then assessing children in Experiment 2. Both good and poor child readers were tested in this second experiment. While **Experiment 2** implicitly tested children on their sensitivity to stress (not explicitly required in a lexical decision task), in **Experiment 3** sensitivity to stress was tested more explicitly by assessing the differences between good and poor readers in a word-type categorization task using only typical verbs and nouns marked by iambic and trochaic stress, respectively. Use of lexical stress is not necessary in this task, but if identified as a type of suprasegmental information, then it can be used to facilitate the response decision. Having tested sensitivity to stress when it is not required, but could be helpful, the next test involves when it is explicitly required. **Experiment 4** assesses the ability of good and poor readers to identify either the noun or the verb in aurally presented noun/verb minimal pairs where the words in each pair differ only in stress location (contrastive pairs). From the perception of stressed words to the short-term memory of stress information, **Experiment 5** assesses the reader's ability to process lexical stress contrasts in a same-difference task, for contrastive noun/verbs (different) or a repeated word (noun/noun or verb/verb; same) minimal pairs. The ISI (memory component) was varied from 50 ms to 500 ms. Finally, **Experiment 6** looks at whether stress can be interfering, as well as facilitatory, in an auditory priming task, where the prime and target have contrastive lexical stress.

The **Summary** discusses the outcomes of these experiments in terms of experimental paradigms used, spoken word recognition and the sensitivity to lexical stress between good and poor readers.

2 Experiment 1 - Sensitivity to lexical stress in lexical decision tasks

The aim of this experiment is to assess adult sensitivity to lexical stress using "yes/no" and "go/nogo" lexical decision tasks.

Spoken word recognition has been assessed using a plethora of experimental paradigms (for summary, see Frauenfelder & Tyler, 1987; Grosjean & Frauenfelder, 1996). These include auditory lexical decision (Goldinger, 1996; McCusker, Hillinger, & Bias, 1981), speech shadowing (Cherry, 1957; Marslen-Wilson, 1973), phoneme monitoring (Foss, 1969; Frauenfelder & Sequi, 1989), gating (Grosjean, 1980), and word spotting (Black & Byng, 1989). There is also a great body of work investigating spoken word recognition using neuro-imaging techniques (van den Brink, Brown, & Hagoort, 2001).

The lexical decision task is one of the most widely used experimental paradigms; a literature search indicates that over 5000 experiments referred to lexical decision tasks. Lexical decision tasks assess the participant's knowledge of words under speeded conditions (Meyer & Schvaneveldt, 1971), and in the case of aural item presentation requires a listener to respond whether a sound heard is either a word or a non-word. Using a discrete stage model of performance Perea, Rosa and Gomez (2002) defined the temporal stages of a lexical decision task as: 1) lexical selection, 2) response decision, and 3) response selection. The *Lexical selection* stage is when the input stimulus matches entries in the lexicon, similar to what Frauenfelder and Tyler (1987) described, in the Introduction. The *response decision* stage is where a decision is made that the match is successful and the stimulus is a word (or not). The *response selection* stage in a "yes/no" lexical decision task (Meyer & Schvaneveldt, 1971) is when the participant decides whether to press either a “yes” or “no” response button. Detractors of the "yes/no" lexical decision task (Perea, Rosa, & Gomez, 2003) argue that a large part of the response time is due to this non-lexical *response selection*, which may involve additional and irrelevant processes (Pachella 1974).

A simplified version of the lexical decision task was suggested by Gordon and Carramazza (1983) who recommended that participants focus on the lexical and response decision only, by responding to words only, hence greater sensitivity to the lexical selection and response decision stages. In this “go/nogo” task no response is required if the item is not a word. Consequently, the response times for the "yes/no" lexical decision task will be slower than the response times for the "go/nogo" lexical decision task (Chiarello, Nuding, & Pollock, 1988; Gibbs & Van Orden, 1998; Gordon, 1983; Hino & Lupker, 1998, 2000; Measso & Zaidel, 1990). In a recent study, Gomez, Ratcliff and Perea (2007) suggest that the "go/nogo" lexical decision task results in fewer errors because pressing one button should minimize variability and therefore the “go/nogo” lexical decision task’s variability should be less than the “yes/no” lexical decision.

One of the reasons for examining the suitability and sensitivity of the “go/nogo” lexical decision task is to assess whether it might be appropriate for children with reading difficulty. There are a number of research papers published using the “go/nogo” lexical decision task, but very few actually address spoken word recognition with younger participants. In 2011, Moret-Tatay and Perea addressed this issue and assessed the suitability of the “go/nogo” lexical decision task with 24 second grade (aged 7-8 years) and 24 fourth-grade (aged 9-10) children. Using visually presented items, they found that the “go/nogo” lexical decision task produced faster response times, fewer errors and it had less variability than the “yes/no” lexical decision task. Furthermore, the "go/nogo" lexical decision task was sensitive enough to find a speed difference between second and fourth graders latency responses to the stimuli.

The second experiment in this thesis will address the suitability of the “go/nogo” lexical decision task with children. This experiment assesses the adults’ sensitivity to the “yes/no” and “go/nogo” lexical decision tasks. This thesis differs from the Moret-Tatay and Perea (2011) study, in that it assesses spoken word recognition, where the words are disyllabic words with trochaic and iambic stress patterns. Furthermore, this first experiment assesses the lexical sensitivity to spoken disyllabic words of adults who are proficient English speakers.

Since proficient English participants rely less on suprasegmental features in spoken word recognition, a way to force listeners to attend to suprasegmental features was to use extrinsic factors; that is the items in the list are such that they bias a response to match the explicit manipulation in the list. For example, Connine, Titone and Wang (1993) manipulated the items in a list in a phoneme completion task. The participants heard a part-word where the first phoneme was excised (eg. /?est/) and were asked to complete a spoken word, by responding with the missing phoneme. They found that participants would select a high-frequency word /<u>b</u>est/ rather than the low-frequency word /<u>p</u>est/. This frequency assigned to words like

/b̲est/ was deemed the word’s *intrinsic* frequency. In subsequent experiments, Connine and colleagues added high-frequency filler words to the list, and found that participants select mostly high-frequency words. However, when they added low frequency words to the lists, they found that participants selected mostly low-frequency words. They termed the frequency assignment that is dependent upon the listed items, the *extrinsic* frequency as it had been explicitly manipulated through extrinsic factors. More recently, Vitevitch (2003) tested 78 university students who were native English speakers in a same/different task, which is when you present two items and the participant has to respond in the positive if the items are the same or the negative if they are different. He wanted to ascertain whether the participants would use pre-lexical or lexical processes to make same/different decisions. He set three conditions, the first used mostly word fillers, the second used an equal number of words and non-words, and the third condition used mostly non-words as filler words. He found that lexical processes were utilised in condition 1 – where the items were mostly words, and sub-lexical processes were utilised in condition 3 where the filler words were mostly non-words.

In order to bias the participants in this experiment (and Experiment 2) to process suprasegmental features pre-lexically, I have included non-words in the lists that are illegal non-words, which violates the English phonotactic rules. Half of the non-words had a rising pitch (iambic) and the other half had a descending pitch (trochaic) so that the acoustic/phonemic processes (McQueen, 2005) favoured pre-lexical processing. Note the same items will be presented to 8-11 year old children in Experiment 2, and this research is interested in how poor readers would process these items considering that they rely more on phonological processing (Mattys & Melhorn, 2005; Mattys, Pleydell-Pearce, Melhorn, & Whitecross, 2005).

Given the extrinsic factors in the list of stimuli and the expectation that adults would utilise lexical stress, then words with trochaic stress patterns will have a temporal advantage as the stress on the first syllable is used to begin lexical access (Cooper, et al., 2002; Soto Faraco, et al., 2001). Word recognition for iambic items should be slower, as the second stress syllable has a temporal delay. Cutler (1989) suggested that the second syllable may be used to access the lexicon and the first syllable is then processed retroactively, thus delaying the word recognition of iambic items relative to trochaic bisyllabic words. It's not exactly clear how this mechanism for retroactivity works, but it does require additional processing and memory storage because you have to remember the first syllable (Mattys & Samuel, 2000) resulting in slower word recognition for iambic words and the likelihood of generating more errors. In addition to the temporal advantage of lexical stress, word frequency should also affect spoken word recognition.

Spoken word frequency effects are robust; high-frequency words have a processing advantage over low-frequency words. Advantage on high-frequency words may be observed in faster response times and more accurate responses when the stimulus information is sufficient (Marslen Wilson, 1987). Word frequency is explained in most of the current spoken word recognition models: "Cohort" Model (Marslen Wilson, 1987); TRACE (McClelland & Elman, 1986) and Neighbourhood Activation Model (Luce & Pisoni, 1998).

Therefore, if we combine the frequency effects and lexical stress we would expect that high-frequency trochaic words would be recognised much faster than low-frequency trochaic words. Similarly, if there is no interaction between frequency and lexical stress, we could expect iambic words to be recognised slower than trochaic words, and low-frequency iambic words to be slower than high-frequency iambic words. However, the research by Arciuli and Cupples (2003, 2004) suggest that there might be an interaction between frequency and lexical stress, when the stress assignment is typical of a grammatical class (Davis & Kelly, 1997). That is, the bisyllabic words are typical (i.e. trochaic nouns and iambic verbs) and atypical (iambic nouns and trochaic verbs). To this end the words selected for this experiment, are low and high-frequency bisyllabic nouns with both trochaic (e.g., KITten) and iambic (e.g., aDDRESS), and bisyllabic verbs that are trochaic (e.g., CANcel) and iambic (e.g., forGET).

It is therefore hypothesized that

1. Using disyllabic words and non-words, the auditory “go/nogo” lexical decision task will have shorter response times, less response time variability and fewer errors than an auditory "yes/no" lexical decision task; and it will be more sensitive to lexical stressed affects.
2. Given that lexical stress constrains lexical access, the trochaic words will have a temporal advantage and will be recognised faster and have fewer errors than iambic words.
3. For those verbs and nouns that have typical stress in their class, there will be an interaction between typicality and frequency, where the recognition

of typical words will have shorter response latencies to atypical items for low-frequency words only.

2.1 Method

Participants

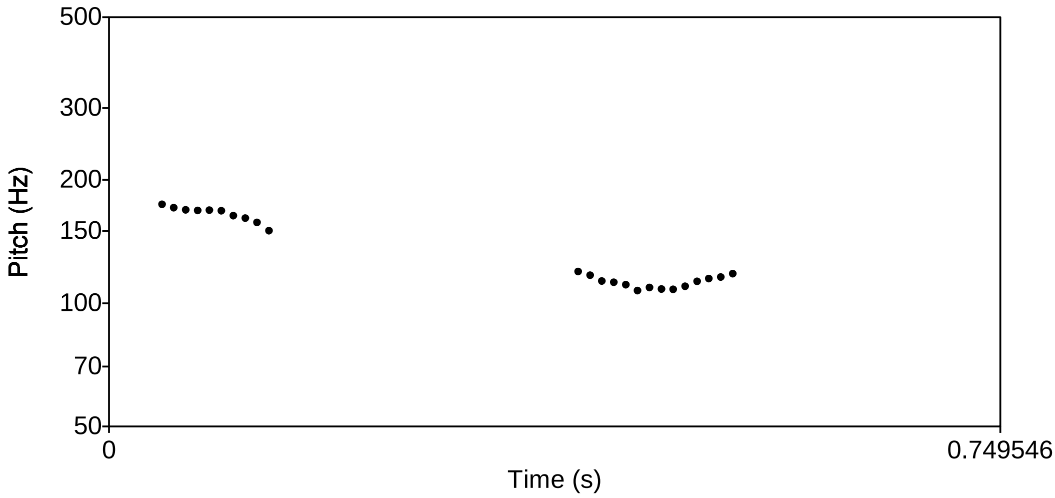
Seventeen adults with normal hearing (self-reported) took part in this experiment. There were 7 males *M* = 38;5 years (*SD* = 15;1 years) and 10 females *M* = 34;7 years (*SD* = 9;8 years). They all reported English to be their first language.

Material

A set of 120 disyllabic nouns and verbs were extracted from the MRC database (Coltheart, 1981). The 120 disyllabic words consisted of 60 trochaic words (e.g., KITchen) and 60 iambic words (e.g., ciGAR). A set of 120 disyllabic non-words, which violated the English phonotactic rules, was selected from the ARC Non-word database (Rastle, Harrington, & Coltheart, 2002).

The stimuli were recorded using a male speaker of English (the researcher). The target words were pronounced according to the phonetic description provided in MRC database (Coltheart, 1981). Since a primary aim was to assess lexical stress in words, it was important to ensure that the target word did not have unusual pitch and/or longer duration on the last syllable. Therefore, target words were recorded in carrier sentences; for example, "the *kitchen* is green" or "please *record* the item". Moreover, to ease the later splicing of items, care was taken not to co-articulate the target word with preceding or subsequent words.

The items were recorded at 44.1 KHz at 16bit using PRAAT software (Boersma & Weenink, 1992-2007) and the same software was used to splice the words and non-words from the recorded carrier sentences. Stressed syllables have higher pitch, longer duration and higher amplitudes (Lehiste, 1970). The spectrographs of the target words and non-words were visually inspected to ensure that trochaic items had descending fundamental frequencies (refer to Figure 1) and iambic items had ascending fundamental frequencies (refer to Figure 2).



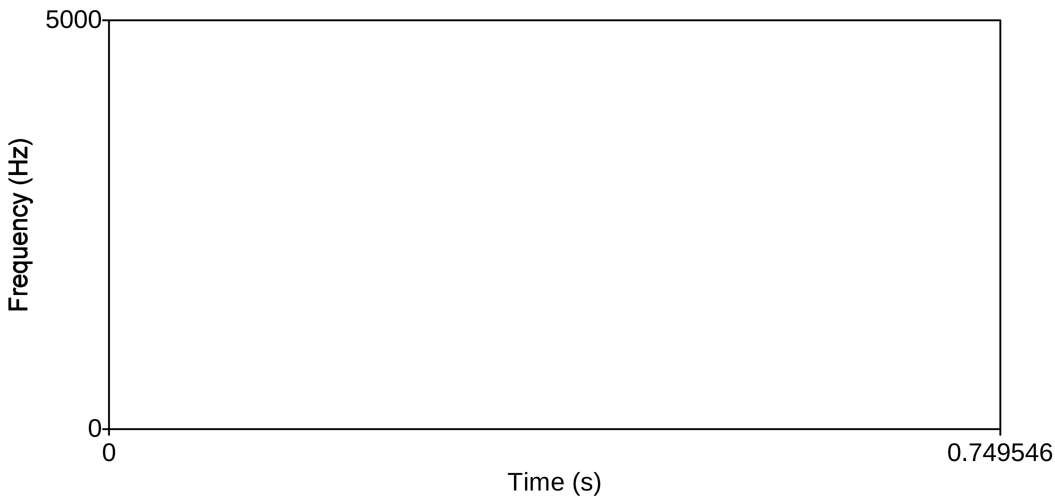


Figure 1. Theverage pitch contour and sound spectrograph (at bottom) of a trochaic word.

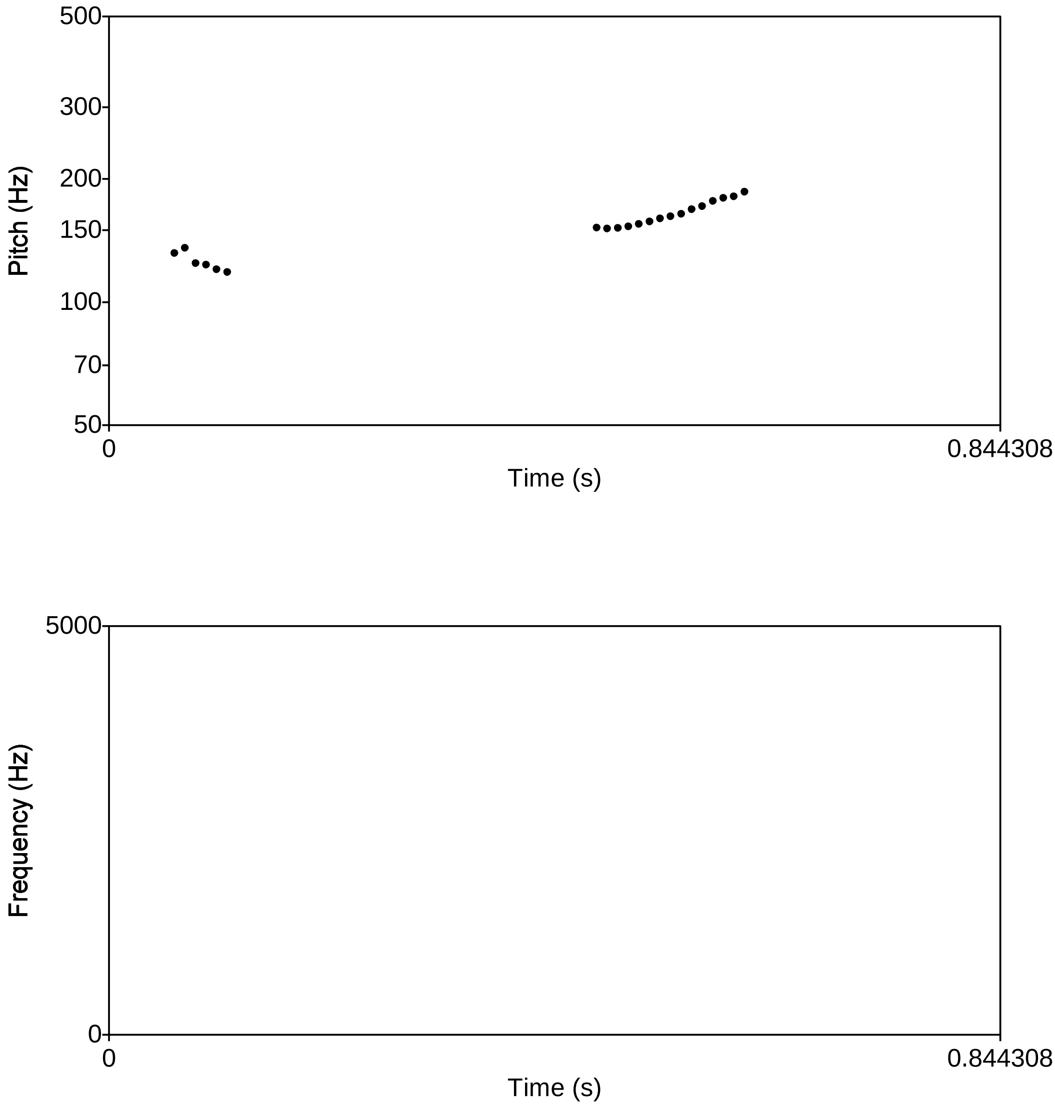


Figure 2. The average pitch contour and sound spectrograph (at bottom) of an iambic word.

Since spoken word frequency, phonological neighbourhood, neighbourhood frequency, and the number of phonemes are factors that affect word recognition, the sample of words selected was measured on these properties. All word statistics were recorded using the N-Watch program by Davis (2005). The cut-off spoken word frequency ranges were as follows: for *Low-frequency* Iambic Verbs (0.8-25), iambic nouns (2-14), trochaic verbs (3-15), trochaic nouns (5-10); and *high-frequency* Iambic Verbs (44-200), iambic nouns (46-175), trochaic verbs (51-196), trochaic nouns (62-155). The same items and cut-off ranges were used in experiment 2.

Separate ANOVAs were conducted to ascertain differences between frequencies, numbers of phonological neighbours, summed frequency of phonological neighbours and number of phonemes. Spoken word frequency for iambic words M = 44.5 (SD = 83.25) and trochaic M = 37.86 (SD = 54.63) were not significantly different ($F < 1$). Phonological neighbourhood size for iambic M = 2.83 (SD = 1.95) and trochaic M = 3.37 (SD = 2.01) words were again non-significant (F < 1). Andrews (1992) has shown that some items with low-frequency but with high neighbourhood density do outperform items with high-frequency in dense neighbourhoods. To reduce the effects of this confound we made sure that the summed frequency for each of the phonological neighbours was also not significantly different ($F < 1$) for iambic M = 20 (SD = 33.76) and trochaic words M = 15.47, (SD = 25.23). The more phonemes in a word, the more time is required to identify the word(s). Word phoneme lengths varied between 4 and 8 phonemes with no significant difference ($F(1,112) = 2.15$, $p > .05$) between iambic words M = 4.94 (SD = .96) and trochaic words M = 4.85 (SD = .92). One list consisted of 24 practice words and non-words. The second list consisted of 120 disyllabic words (refer to Appendix A) and 120 disyllabic non-words.

A study by Dupoux and Mehler (1990) suggested that response times are unaffected by *file length* of recorded disyllabic words in a phoneme detection task. They compressed recorded disyllabic sound items to be shorter in duration (file length) than uncompressed monosyllabic words. Their results showed no word length effects for the compressed disyllabic words. Therefore given that sound files had differing lengths (refer to Table 1) the RTs were not adjusted to include the Covariance of file lengths.

Table 1

Mean file duration in milliseconds (and SD in brackets) for each of the stimulus groups.

	Lexical stress	
Frequency	Iambic	Trochaic
LF	637.5 (73)	518 (96)
HF	662.5(88)	518 (89)

In addition to these items, a TOWRE filler task was used between the "yes/no" and "go/nogo" lexical decision tasks. The “Test of Word Reading Efficiency” (TOWRE: Torgesen, Wagner, & Rashotte, 1999) is a reading performance test with two components. Each measures the number of items that can be named in 45 seconds. The first list provides a measure of sight word reading, and involves a list of words. The second list measures phonemic decoding, and involves a list of phonotactically legal (in English) non-words. The TOWRE assesses sight word reading efficiency and phonemic decoding efficiency. Given that the age range of the participants was beyond the required age range (6;0-24;11 years) for the TOWRE test, the reading ability of adults was not analysed; but the procedure was practiced for later use with children (Experiments 2 to 6).

Procedure

The two lexical decision tasks were counterbalanced with each alternate participant started with a “yes/no”, while the other started with a "go/nogo" lexical decision task. Both lexical decision tasks contained the same items. After the participants completed the first list of 240 items, they completed a TOWRE filler task, to reduce any pre-exposure effects. They then proceeded with the next 240 items. Each list of items was scrambled, giving each participant a unique order of the trials.

The DMDX stimulus presentation software (Forster & Forster, 2003) was used to present the auditory stimuli and to record the response times (RTs) and error rates. Each DMDX trial consisted of a fixation point (+) in the middle of the screen for 500 ms. The stimulus item was then presented via headphones and the participant had 2000 ms to respond. The response time was recorded from the onset of the target word. Each of the trials ended with either a correct or an error feedback. Participants were instructed as follows:

> You will hear a sound. Your task is to decide if that sound is a word or not. *In the “go/nogo” case:* If the sound is a word, press the Shift key as quickly as possible. If the sound is not a word, do not press anything. *In the “yes/no”*

case: If the sound is a word, press the Right Alt key as quickly as possible. If the sound is not a word, press the Left Alt key as quickly as possible. A smiley face ☺ will tell you if you made the correct decision. A frowning face ☹ will tell you if you made the wrong decision.

Participants were tested individually in a sound attenuated room. Each participant was tested on a desktop computer. Sound was relayed through earphones at a comfortable volume. Each task took about 8 minutes to complete, with two planned breaks every two and half minutes.

2.2 Results

Correct responses and error rates were calculated using response times (RTs) between 250 ms and 1500 ms. Only correct response rates were reported in all experiments (except experiment 4, which was winsorised). All values below 250 ms and above 1500ms were deleted (treated as missing data) while remaining values which were above or below 2SD from the mean (relative to condition) were trimmed to the 2SD value. Using this range of response times resulted in no participants being excluded for further analysis because none had more than 20% errors. In total, 4.2% of items in the "yes/no" lexical decision task and 2.1% in "go/no-go" lexical decision task were trimmed.

Participants' mean response and error rates are presented in Table 2 and Table 3.

Table 2

Mean and standard deviation in brackets for RTs in milliseconds for each Task Type by Word Type, Lexical Stress and Word Frequency.

	Verbs				Nouns			
	Iambic		Trochaic		Iambic		Trochaic	
	LF	HF	LF	HF	LF	HF	LF	HF
YN LDT	786(89)	832(86)	843(67)	777(71)	882(79)	805(70)	814(74)	768(69)
GNG LDT	780(96)	845(99)	838(85)	771(93)	876(99)	819(88)	792(71)	737(67)

YN = "YES/NO", GNG = "GO/NOGO"

Table 3

Mean and standard deviation in brackets for percentage errors for each Task Type by Word Type, Lexical Stress and Word Frequency.

	Verbs				Nouns			
	Iambic		Trochaic		Iambic		Trochaic	
	LF	HF	LF	HF	LF	HF	LF	HF
YN LDT	1.9(3.1)	2.8(4.1)	5.6(6.4)	5.9(5.2)	7.1(7.2)	4.4(7.4)	11.0(10)	1.1(2.6)
GNG LDT	0.8(2.3)	0.4(1.6)	5.2(4.5)	1.6(3.7)	3.6(3.5)	0.8(3.2)	3.6(5.3)	0.0(0.0)

YN = "YES/NO", GNG = "GO/NOGO"

Participant response latencies and error rates were analysed through separate ANOVAs. The first ANOVA assessed Task Type ("yes/no" v "go/nogo") x Lexical Stress (Trochaic v Iambic) x Word Type (Noun v Verb) x Word Frequency (High v Low), all within-subject factors.

Analysis of lexical decision differences

Response latencies: There was no four-way interaction ($F < 1$). The first hypothesis predicted faster RTs, fewer errors and less variability in the "go/nogo" lexical decision task when compared to the "yes/no" lexical decision task. In terms of RTs, there was no significant difference in overall response latency between the two response tasks (6ms; $F < 1$). The two-way interaction (*Figure 3*) between Task Type and Lexical Stress ($F(1,16) = 6.36$, $p = .023$, $\eta^2 = .28$)[3] was significant.

[3] (Note, partial eta squared (η^2) values between 0 and 1 will be interpreted as follows: 0-0.1 is a weak effect, 0.1 – 0.3 is modest effects, 0.3-0.5 is a moderate effect, and > 0.5 is a strong effect)

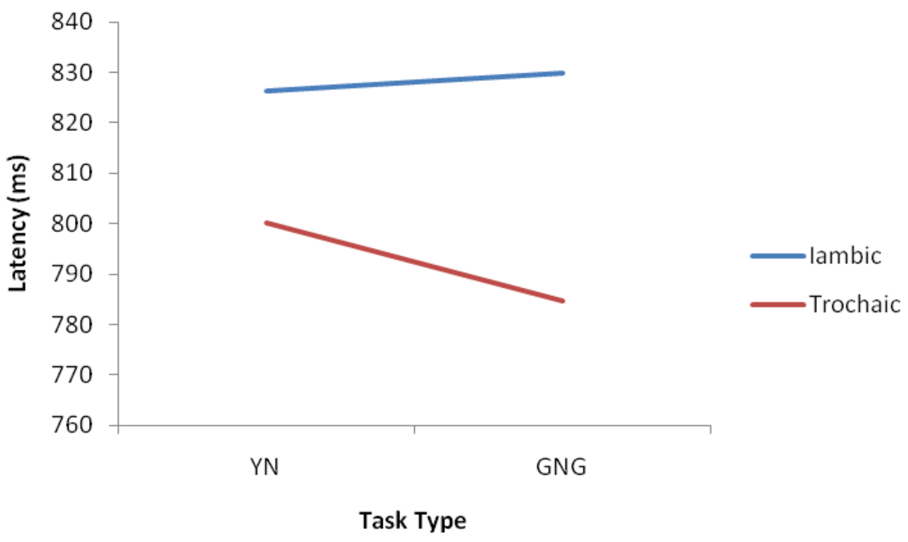


Figure 3. Mean response latencies between the "Yes/no" lexical decision task (YN) and "go/nogo" lexical decision task (GNG).

An analysis of simple effects showed that while trochaic items were 26ms faster than iambic items in the "yes/no" lexical decision task $(F(1,16) = 12.31, p = .003, \eta^2 = .44)$ this difference increased to 42 ms on the "go/nogo" lexical decision task $(F(1,16) = 52.01, p < .001, \eta^2 = .77)$. The "go/nogo" lexical decision task was better for trochaic items, but not for iambic items (refer to *Figure 3*). The longer time waiting to process the second syllable, may have masked any advantage bestowed by "go/nogo" lexical decision task.

Effect sizes (partial ETA-squared) showed a moderate RT effect for the "yes/no" lexical decision task, but a strong RT effect size for the "go/nogo" lexical decision task. The source of the interaction were the relatively quicker trochaic responses in the context of the "go/no-go" lexical decision task , supporting the hypothesis that the "go/no-go" lexical decision task would show a stronger effect for stress but no faster response times for iambic items.

Variability: One of the claims for using a "go/nogo" lexical decision task is that it minimises variability as measured by standard deviation. Univariate analysis of the items in Table 2 above revealed that the response time standard deviation for the "yes/no" lexical decision task M = 75.63 was significantly lower ($F(1,14) = 5.24$, p = .038, η^2 = .27) than the "go/nogo" lexical decision tasks M = 87.57. On the other hand, in Table 3 the error standard deviation for the "yes/no" lexical decision task M = 5.84 was significantly higher ($F(1,14) = 6.56$, p = .023, η^2 = .32) than for the "go/nogo" lexical decision tasks M = 3.03.

Analysis of Lexical stress, Word type and Frequency

There was a significant three-way interaction between Lexical Stress x Word Type x Frequency ($F(1,16) = 99.16$, $p < .001$, $\eta^2 = .86$). In order to analyse this 3-way interaction, I have analysed three 2-way interactions, which were all significant. There was a 2-way interaction between Word Frequency and Lexical Stress ($F(1,16)$ = 41.68, $p < .001$, η2 = .72) (refer to Figure 4)

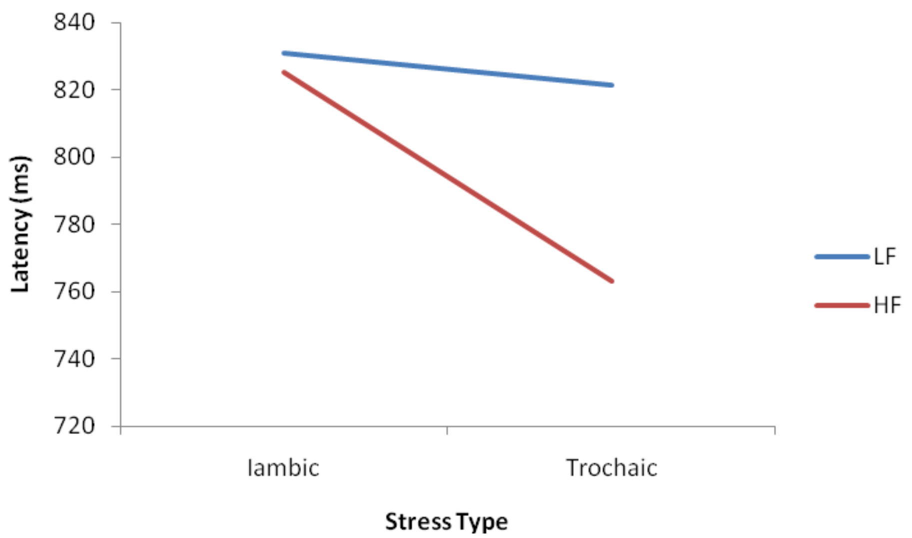


Figure 4. Mean response latencies between high-frequency (HF) and low-frequency (LF) items for each level of Stress Type

Assuming that lexical stress assists lexical access, words with trochaic stress should show an advantage. Analysis of simple effects suggested that trochaic items were significantly faster than iambic items for high-frequency only ($F(1,16) = 108.80$, $p < .001$, $\eta2 = .87$), which contributed 32ms to a frequency main effect ($F(1,16) = 70.0$, $p < .001$, $\eta^2 = .81$). There was no significant frequency effect for iambic items ($F(1,16) = 1.35$, $p = .26$, $\eta^2 = .19$)

The interaction between Word type and Frequency ($F(1,16) = 35.54$, $p < .001$, $\eta2 =.69$) supports this finding (refer to *Figure 5*), with Nouns showing a 58.35ms difference between low-frequency and high-frequency words ($F(1,16) = 159.74$, $p < .001$, $\eta2 = .91$). However, the interesting observation was the 6ms difference between low and high-frequency verbs was insignificant ($F < 1$), suggesting a processing advantage for the low-frequency verbs or lack of advantage for high-frequency verbs.

Figure 5. Mean response latencies between high-frequency (HF) and low-frequency (LF) items for each level of Word Type

The interaction between Word type and Lexical Stress $F(1,16) = 78.51$, $p < .001$, $\eta 2 = .83$) indicated that trochaic nouns showed a 67.74 ms processing advantage over iambic nouns *(F(*1,16) = 92.96, $p < .001$, $\eta 2 = .85$) (refer to *Figure 6*).

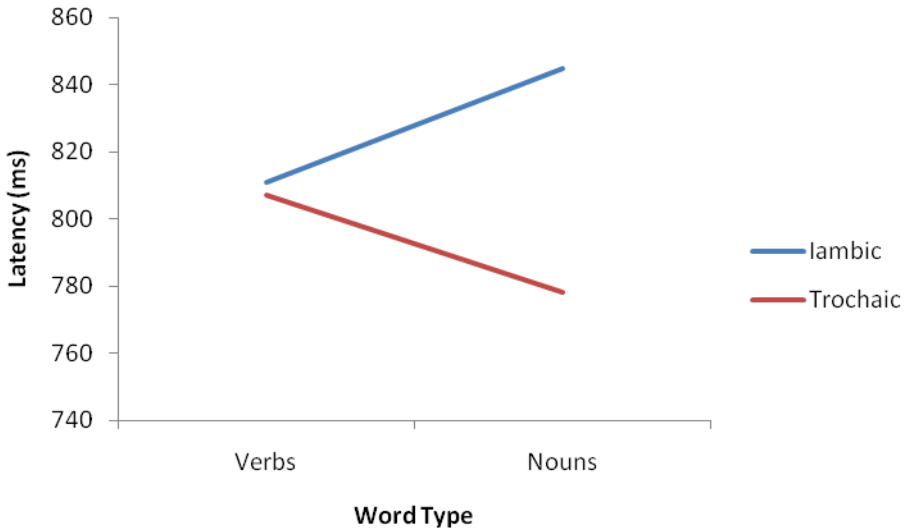


Figure 6. Mean response latencies between Noun and Verb for each level of lexical stress

However, the difference between iambic and trochaic verbs was not significant t (F < 1), which may be due to typicality; that is the typical iambic verb might have better performance for low-frequency items (refer to *Figure 5*).

Errors: A similar ANOVA to the response rates was conducted for the error responses. There were no significant 4-way interactions, but there was a significant 3-way interaction between TaskType x Word type x Frequency ($F(1,16) = 5.68$, $p = .03$, $\eta 2 = .26$) (refer to *Figure 7*). The interaction between word type and frequency for the "go/nogo" lexical decision task was not significant (refer to *Figure 8*).

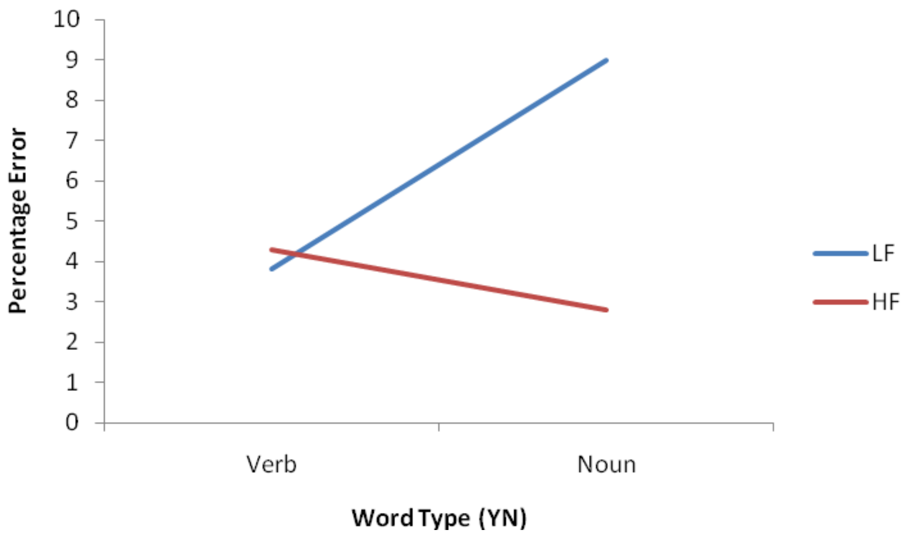


Figure 7. Mean Errors between low-frequency and high-frequency items for each level of word type for the YN Task Type

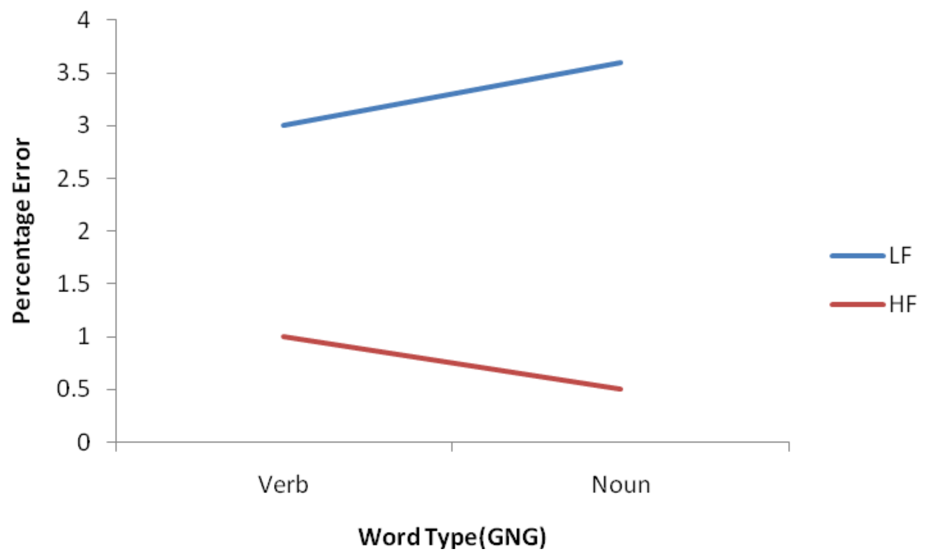


Figure 8. Mean Errors between low-frequency and high-frequency items for each level of word type for the GNG Task Type

Further analysis showed (refer to *Figure 7*) that nouns had 5.26 more errors than verbs for low-frequency items in the "yes/no" lexical decision task only ($F(1,16) = 8.43$, $p = .01$, $\eta^2 = .35$). These noun errors contributed to the main error difference between the "yes/no" and "go/no-go" lexical decision tasks ($F(1,16) = 14.33$, $p = .002$, $\eta^2 = .47$).

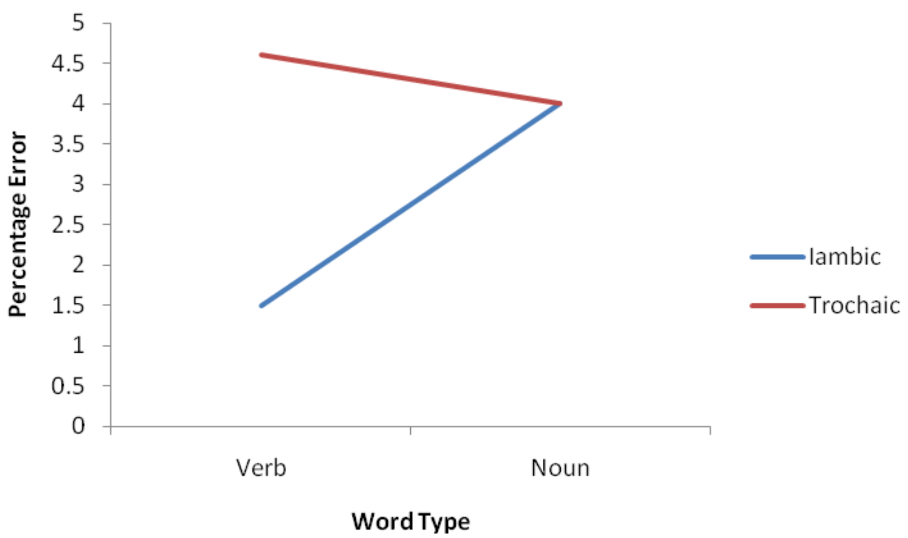


Figure 9. Mean Errors between Iambic and Trochaic items for each level of word type.

There was also a 2-way interaction between Word Type and Lexical stress ($F(1,16) = 13.4$, $p = .002$, ŋ2 = .46) refer to *Figure 9*. Further analysing of the word type by lexical stress interactions showed that iambic verbs had 2.6% fewer errors than the trochaic verbs, which does not support the notion that trochaic items have a process advantage. The results suggested a typicality effect, where iambic verbs, which are typical in their grammatical class, had fewer errors.

Post-hoc analysis

From the analysis above it appeared that iambic verbs (refer to *Figure 6*) had a processing advantage and that this advantage was linked to low-frequency items (refer to *Figure 5*). One possibility is typicality; that is, the iambic verb, which is typical in its grammatical class, performs better at low-frequency. A further Task Type x Typicality x Word Type x Frequency ANOVA was conducted to assess typicality in general, and in particular, whether there were differences between typical and atypical low-frequency items. Typical items are iambic verbs and trochaic nouns, whereas the atypical items consist of iambic nouns and trochaic verbs. The result showed an interaction between frequency and typicality ($F(1,16) = 99.16$, $p < .001$, $\eta^2 = .86$).

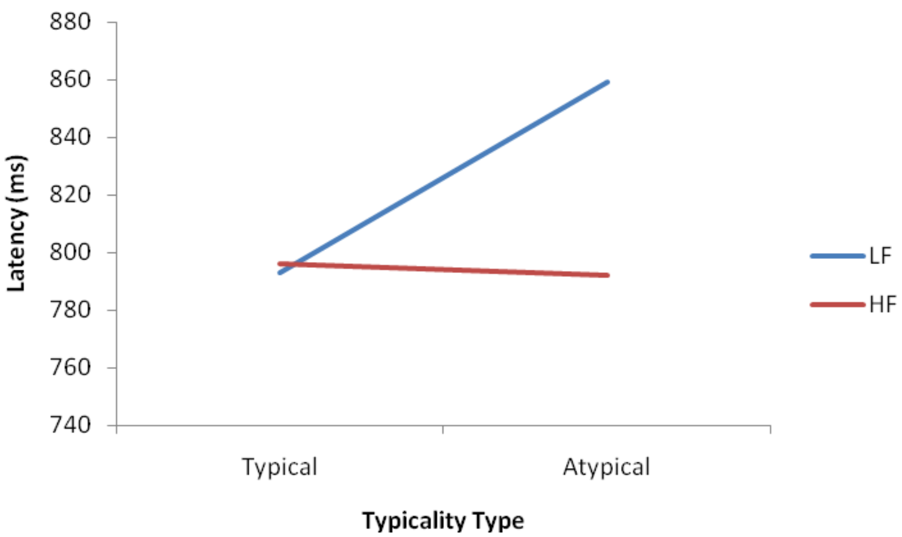


Figure 10. Mean response latencies between Typical and Atypical items for each level of Frequency.

Analysis of simple effects of the interaction above (*Figure 10*) suggested that responses to typical items were 66.7ms faster than responses to atypical items ($F(1,16) = 140.44$, $p < .001$, $\eta^2 = .90$) showing strong typicality effects and lexical stress sensitivity.

Error Trade-off: For an error trade-off to exist, the fastest items should also have the highest errors, and there should be a negative correlation between RT and the number of errors for the specific items. Verbs were recognised slower and high-frequency nouns were recognised the quickest, however, they did not have the most errors; it was the low-frequency trochaic items that had the most errors, suggesting that there was no speed-accuracy trade-off. This is confirmed by the lack of correlation between Noun RTs and errors for ($r(15) = -.14$, $p > .10$)

2.3 Discussion

The first hypothesis was partially supported. Overall, the auditory “go/nogo” lexical decision was not significantly faster than the “yes/no” lexical decision task; however, the “go/nogo” lexical decision task did have fewer errors than the “yes/no” lexical decision task, with the highest proportion of these errors concentrated on the low-frequency trochaic items. The “go/nogo” lexical decision task appeared to be more sensitive to trochaic lexical stress (refer to *Figure 4*). Concerning the variability of the “go/nogo” lexical decision task, the percentage of errors did show less variability; but the response times were not less variable in the “go/nogo” lexical decision task. The second hypothesis was supported, trochaic words were recognised faster albeit for the high-frequency items only, which contributed to a main effect of trochaic items performing better than iambic items overall. There was a frequency effect for trochaic items but not for iambic items. The last hypothesis was also supported, some of the items that are typical in their class did interact with frequency, particularly the iambic verbs showed better latency and fewer errors than trochaic items. Each of these findings is discussed below.

2.3.1 Lexical decision differences

It was expected that word recognition in the “go/nogo” lexical decision task would show faster response latencies than the “yes/no” lexical decision task (Chiarello et al., 1988; Hino & Lupker, 1998; Perea & Pollatsek, 1998). Contrary to the orthographic lexical decision task studies (Hino & Lupker, 1998, 2000) the auditory "yes/no" and "go/nogo" lexical decision tasks did not show differences in response latencies. Part of the issue could be the difference in processing written words and spoken words in a lexical decision task. For example, auditory and orthographic trochaic items should not differ that much as each *starts* the word recognition process. The auditory trochaic items start word recognition processes because the strong first syllable, which initiates lexical access, is perceived first; and this is similar to processing orthographic script from left-to-right, the word recognition processes have started. The results showed that the “go/nogo” lexical decision task was more sensitive to trochaic items. Given that lexical decision could begin to be made after processing the first syllable, the elapse time for word recognition is shorter; and, if lexical access has occurred during the allotted time after word onset, it would be easier to recognise trochaic words and confirm in the positive. The processing of auditory iambic words (eg. forGET), which initiates lexical access after the first syllable, is different; and the benefit of processing a “yes/no” or “go/nogo” lexical decision task is not realised (refer to *Figure 3*) in the auditory paradigm..

One expects fewer errors in the “go/nogo” lexical decision task. Low-frequency items elicit more errors because it takes longer to identify the item. Gomez et al. (2007) provide the following reason in a "yes/no" lexical decision task. “When an unfamiliar low-frequency word is encountered, participants may make a non-word response, and these trials end up counting as errors and not contributing to the mean correct latency for low-frequency words” (Gomez et al., 2007, p. 390). That’s perhaps why trochaic low-frequency words (refer to *Figure 7* and *Figure 9*) in the "yes/no" lexical decision task were the primary cause of errors; because the low-frequency items took too long to be recognised and the participant made a premature wrong decision which resulted in more errors.

“The go/no-go task provides more time for word dynamics to run toward coherent states relative to the two-choice procedure, in which participants are more likely to misclassify the word stimulus as a non-word” (Gomez et al., 2007, p. 390). Since the high-frequency trochaic items had shorter response latencies, it was expected that there might be an error trade-off; that is, the faster the recognition, the more errors are created. However, the results suggest that there was no error speed trade-off for the trochaic nouns, as most of the errors were encountered in the low-frequency condition.

Is the "go/no-go" lexical decision task more sensitive to lexical stress? A high standard deviation expresses high variability within the sample. Contrary to expectation, the "go/nogo" lexical decision task was not less ‘noisy’ than the "yes/no”-lexical decision task. Other studies (Hino & Lupker, 2000; Measso & Zaidel, 1990) also support the current findings that "go/nogo" lexical decision task is not less variable than the "yes/no" lexical decision task. For example, the "go/nogo" lexical decision task had shorter response latencies and it was expected that it would also show shorter variations and hence smaller standard deviation; this was indeed the case in this experiment. In *Figure 3*, the "yes/no" lexical decision task showed a moderate effect size as measured by partial ETA-squared (η^2). The "go/no-go" lexical decision task showed a much larger effect size, and was therefore more sensitive to the processing of lexical stress.

2.3.2 Frequency and Typicality differences

The absence of frequency effects for the iambic words suggests a different processing strategy for these disyllabic words (refer to *Figure 4*). When the items access the lexicon the assumption is that, the lexicon will process these items in a frequency order. Using the Cohort Model as an example, as the iambic items is processed the first syllable creates a list of possible words all starting with the same phonemes. In addition, frequency processing also starts by processing the items selected because of the unstressed initial syllable in frequency order. When the second stressed syllable is processed, it creates a new trace (refer to Experiment 6) and the first syllable has to be retroactively processed, thus negating the frequency attenuated search that started at word onset causing delays. The expectation therefore is that iambic item processing for low-frequency should be recognised the slowest; and the difference between high-frequency and low-frequency iambic words, will match the difference between the high-frequency and low-frequency trochaic items. However, the interaction showed that low-frequency iambic verbs had better response latencies, and one of the reasons for this advantage could be typicality, as shown in (*Figure 10*). A second option might be that iambic items are processed more at the pre-lexical level. This notion of using more pre-lexical processing for lexical stress is further explored in Experiment 2, 3 and 4 explicitly.

Summary

Experiment 1 provides evidence that the two lexical decision tasks are comparable with the following differences: 1) the "go/nogo" lexical decision task produced fewer errors and faster response latencies for trochaic items; and 2) the "go/nogo" lexical decision task did not show less variability (i.e., "noise") than the "yes/no" lexical decision task when analysing the errors only.

There were robust frequency effects for trochaic items, but not for iambic items, because the interaction between frequency and lexical stress suggests that adult English listeners showed typicality effects for low-frequency items. (This strategy is again explored in Experiment 3). The next experiment explores the differences in word recognition strategies between children and adults; and between good and poor readers.

3 Experiment 2 – Child sensitivity to stress in lexical decision tasks

The Aim of this experiment is to assess child sensitivity to lexical stress using "yes/no" and "go/no-go" lexical decision tasks

This is a repeat of Experiment 1, but this time the participants are 10-12 year old children, some of whom are poor readers. The older the children get, the more they rely on phonotactics. However, without a mature knowledge of phonotactics, poor readers, around 11 years of age, have a higher reliance on lexical stress processing. Research shows that children use stress differently to the way adults use stress. When young children say words, they sometimes reduce the word by omitting syllables. For example, 2-3 years old children will shorten the word “baNAna” and pronounce it as “nana”; a word reduction from right-to-left with falling pitch. Adults, on the other hand, seem to reduce words from left to right. For example, the word “rhiNOceros” is reduced to “rhino” (Carter & Clopper, 2002). A reason for truncating words is provided by the metrical template account (Gerken, 1994). Unlike adults, when young children learn a language like English, they frequently omit weakly stressed syllables from multisyllabic words. These children are more likely to omit weak syllables from word-initial positions than from word-internal or word-final positions. A second account why children truncate words is a bias for detecting iambic syllables in a word. Using the word-final syllables may be derived from acoustic cues such as final-word lengthening effect (Echols & Newport, 1992). One of the attributes of a stressed syllable is that it has longer duration (Lieberman, 1960).

The changes from an iambic bias to trochaic processing suggests a developmental progression with a subsequent shift in bias from iambic to trochaic stress starting at around 4 years for the children and culminating in proficient use of phonotactics around 11 years of age (Atkinson-King, 1973). Wells, Peppe and Goulandris (2004) ascertained how functional prosodic performance changes with age. They tested children aged 5;6, 8;7, 10;10 and 13;9 (years;months) on chunking; that is, the child must indicate if they've heard 2 or 3 items when presented with phrases "fruit-salad and milk" or "fruit, salad and milk". They also tested the children on an affect input task where the participant heard utterances where the final word had a rise-fall pitch indicating "liking" or fall-rise pitch indicating "reservation". The participant then heared a sentence like "it's a very nice garden", where the word garden had a rising pitch or a falling pitch. The participant then had to choose a picture with either a nice garden or overgrown garden. Peppe and Goulandris concluded that younger children 5;6 years had difficulty in perceiving rising pitch, whereas children older than 8 years old cope well with functional contrasts, words with falling (trochaic) or rising pitch (iambic). *Whereas poor readers may still reflect the pre-transitional profile, it's hypothesised that good readers aged between 10-12 (Wells, Peppe & Goulandris, 2004) in this next experiment may have transitioned to processing lexical stress and may also have a trochaic and similar frequency effects as the adults in Experiment 1; in contrast poor readers may not show any frequency effects in RTs and Errors when processing these items.*

If older children (aged 8-12 years) coped with rising and falling pitch (i.e., iambic and trochaic stress) similarly to adults, do they also have similar mental word representations? Radeau (1983) used an auditory lexical decision paradigm to determine semantic priming for both adults and 1st graders (6y, 2m to 7 years). She found similar priming results between adults and children suggesting that the children's lexicon is organized in the same way as adults from a very early age. Edwards and Lahey (1993) also conducted an auditory "go/nogo" lexical decision task with adults and children. They concluded that the lexicons of children and adults were ordered in much the same way, but the children were just slower.

More recently Girbau and Schwartz (2011) replicated the Radeau (1983) study using an auditory lexical decision task. They found that children were generally slower and less accurate than adults, which is partly due to auditory processing in children and semantic networks that are still developing in children in the 8-10 year age group. Part of this delay in response time for children could be dexterity; for example, children were slower than adults when pressing a button repeatedly for 5 seconds (Kail, 1991). *Its therefore hypothesised that, children will be slower than adults when responding to disyllabic items (Edwards & Lahey, 1993).*

Since this experiment contains some poor readers, how would they compare to the good readers, when responding to stimuli in a lexical decision task? Edwards and Lahey (1996) conducted an auditory lexical decision task to assess differences between children with expressive disorders and their typically developing age peers, and found that children with expressive disorder were significantly slower than their peers. To test the children's sensitivity to lexical stress, i*t's hypothesised that children with poor reading skills will be slower than good readers when recognising typical and atypical disyllabic items in auditory lexical decision tasks.*

In Experiment 1 adults showed frequency effects for trochaic items but not for iambic items. The lack of frequency effects for iambic items suggests that adults may have used a different strategy to access iambic words. What Edwards and Lahey (1993) suggest is that adults and older children process words in much the same way. *And therefore, it's hypothesised that good readers would show frequency effects for trochaic items and no frequency effects for iambic items; except they'd be slower than adults in their responses*.

If there are word processing differences between poor readers and good readers, then poor reader too may use different strategies to access bisyllabic words. For example, poor readers may use or rely more on suprasegmental features such as acoustic/phonetic cues to word recognition; and if so, these poor readers would not show frequency effects in word recognition. Good readers on the otherhand may process these bisyllabic words at the segmental level and show frequency effects for trochaic items. *It is therefore hypothesised, poor readers, who are still transitioning from a iambic processing strategy to an adult processing strategy, may not show frequency effects for trochaic items.*

This experiment also ascertains the efficacy of the two lexical decision procedures as in Experiment 1. A literature research showed that the use of the "go/nogo" lexical decision task with children as participants is indeed very rare. In 2011, Moret-Tatay and Perea addressed this issue, by comparing the "yes/no" and "go/nogo" lexical decision task with visual stimuli and using 2nd and 4th graders as participants. This Experiment 2, as far as I'm aware, is a first in assessing the suitability of the "go/nogo" lexical decision task in spoken word recognition with children. I*t's hypothesised that, like Experiment 1, there will be no response latency differences between the "yes/no" and "go/nogo" lexical decision tasks , but there will be error differences between the "yes/no" and the "go/nogo" lexical decision task.*

3.1 Method

Participants

Sixteen children with normal hearing (self-reported) from two local state primary schools in Melbourne took part in this experiment after the parents and guardians of the children provided consent for their children's participation. One of the children, a special needs child, was withdrawn from further participation after her carer found the sessions too demanding. None of these particpants were used in subsequent experiments. The remainder consisted of 7 males (M = 10;5 years, range 10-11;8) and 8 females (M = 10;10 years, range 9;10-11;5). They all reported English to be their first language. Poor readers were identified as having scored below the 25 percentile in the Test of Word Reading efficiency (TOWRE:, Torgensen, Wagner, & Rashotte, 1999). Participant demographics are summarised in Table 4.

Table 4

Age, Sight word and Phonemic scores (standard deviation scores in parentheses) for children identified as good and poor readers.

	Good Reader	Poor Reader
Number of participants	10	5
Age(SD)	10.8 (0.6)	10.8 (0.7)
TOWRE Sight Word(SD)	109 (7.4)	92.6 (3.4)
TOWRE Phonemic decoding (SD)	107 (10.6)	89.9 (1.8)

Total TOWRE (SD)	71.5 (16.9)	22.2 (5.6)

Material

The material used in this experiment was the same as used in Experiment 1. The Test of Word Reading efficiency (TOWRE:, Torgensen et al., 1999), identified poor readers. For the lexical decision tasks, participants were tested using a laptop computer and headsets with volume control (frequency range: 20-20,000Hz, Sensitivity: 100db) which the children could reset to suit their listening comfort. Stimulus presentation on the computer and recording of responses was undertaken using DMDX software (DMDX, Forster & Forster, 2003).

Procedure

The procedure for this experiment was the same as Experiment 1, with the sequence of the task as follows: Lexical decision task, TOWRE, Lexical decision task. The sessions were counter balanced: half of the participant either did the “yes/no” lexical decision task first and the other half did the “go/nogo” lexical decision task first. The trials were similar to those given to adults except that the experimenter verbally explained to the children how to respond to each task.

Another difference between this experiment and the previous experiment was the location. In the previous experiment participants were tested in sound attenuated booths, however in a school setting this was not the ideal. One of the requirements for providing permission to test children at schools was that the child must at all times be in a room where he or she was in full view of teachers and other adult staff at the school. Consequently, these experiments were conducted in a room in a quiet area of the school with occasional extraneous sounds like the ringing of the lunchtime bell.

3.2 Results

Correct responses and error rates were calculated using response times (RTs) between 250 ms and 1500 ms, while those RTs that fell outside of the 2 SD range for each participant were replaced with that 2 SD value (trimming). Some children were quite consistent in identifying the words *Amend, Ruin, Allow, Deceit, Rapport, Saloon* and *Symptom* as non-words, causing error rates above 50%. These items were removed from subsequent analyses. Participant response latencies and error rates were analysed. Participants' mean response and errors rates are presented in Tables 5 and 6.

Table 5

Mean and standard deviation in brackets for RTs in milliseconds for each Task Type by Word Type, Lexical Stress and Word Frequency for poor and good readers.

WordType	Verbs				Nouns			
Lexical Stress	Iambic		Trochaic		Iambic		Trochaic	
Frequency	LF	HF	LF	HF	LF	HF	LF	HF
Poor YN	1005(91)	1016(90)	1059(81)	962(94)	1067(98)	995(95)	927(52)	973(80)
GNG	1004(104)	1031(94)	1008(59)	1001(101)	1007(76)	1022(67)	926(82)	969(144)
Good YN	959(108)	976(118)	982(121)	945(115)	1018(117)	946(109)	906(102)	899(108)
GNG	914(78)	957(112)	944(92)	884(75)	1014(108)	947(69)	888(70)	865(84)

Table 6

Mean and standard deviation in brackets for Percentage Errors for each Task Type by Word Type, Lexical Stress and Word Frequency for poor and good readers.

WordType	Verbs				Nouns			
Lexical Stress	Iambic		Trochaic		Iambic		Trochaic	
Frequency	LF	HF	LF	HF	LF	HF	LF	HF
Poor YN	3.0(4.0)	6.9(9.6)	7.4(5.0)	10.7(7.6)	20.0(17.5)	11.1(10.5)	10.2(8.3)	12.4(7.5)
GNG	6.9(6.7)	11.5(12.9)	14.0(18.0)	10.3(9.8)	17.0(15.1)	9.4(5.0)	8.1(14.4)	1.4(3.2)
Good YN	5.2(7.2)	4.8(7.9)	8.2(7.5)	4.9(5.7)	19.1(24.0)	10.4(10.9)	12.5(9.4)	5.4(6.9)
GNG	2.2(4.9)	2.8(4.9)	3.0(5.3)	1.3(2.8)	12.6(19.5)	3.0(7.4)	3.7(3.9)	2.0(4.5)

Lexical decision task differences

Response latencies: To ascertain if there were overall differences in response latencies between the "go/nogo" and "yes/no" lexical decision task a comparison of the main effects were conducted. According to Perea et. al (2002) the "go/nogo" lexical decision task should show shorter response latencies. For children, the 18 ms (refer to Table 7) difference between the "go/nogo" lexical decision task and the "yes/no" lexical decision task was not significant $F(1,14) = 1.72$, $p = .21$, ns), which is similar to the adult population in Experiment 1.

Table 7

Mean Responses (RT) and Errors with standard deviation (in parentheses) by Task type.

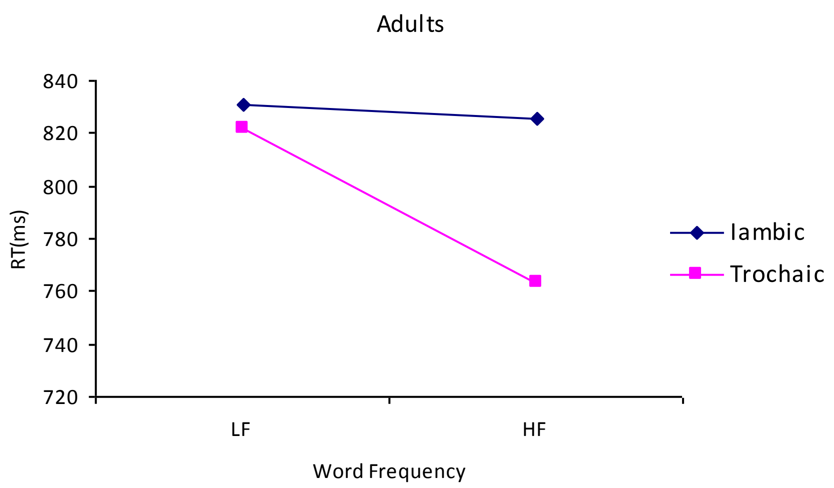
Task Type	RT	SD	Error	SD
Yes/no	968	(98)	9.3	(4.7)
Go/Nogo	950	(83)	5.8	(6.4)

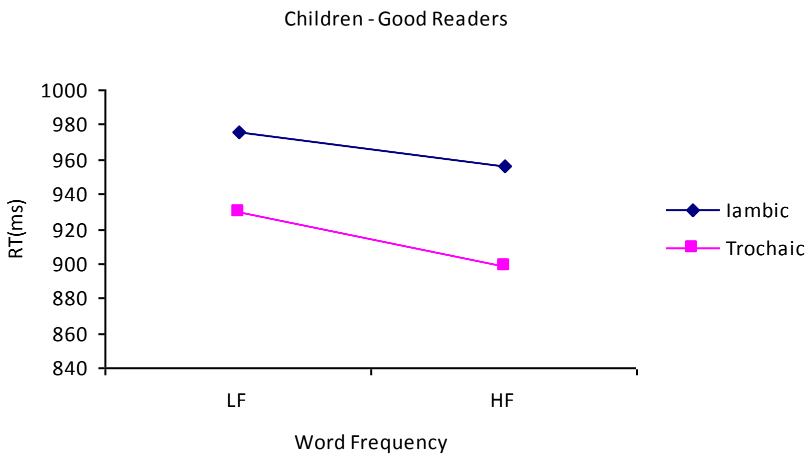
Errors: It was expected that the "go/nogo" lexical decision task should have fewer errors than a "yes/no" lexical decision task. The results supported this expectation, the 3.5% errors for the "go/nogo" lexical decision task were significantly fewer than errors for the "yes/no" lexical decision task ($F(1,14) = 6.70$, $p = .022$, $\eta^2 = .32$).

Variance: One of the claims for using a "go/nogo" lexical decision task is it minimises variability as measured by standard deviation. For variance, the standard deviations were compared using the F-distribution. For response rates there was no significant difference between the two tasks in terms of variance, where ($F(1,14) = 98^2/83^2 = 1.39$, $p = .25$, ns). For errors the variance between the "go/nogo" and "yes/no" lexical decision tasks was similarly not significant, where ($F(1,14) = 6.4^2/4.7^{2\,=}$ 1.85, $p = .19$, ns). In summary, the difference between the "go/nogo" and "yes/no" lexical decision tasks was fewer errors for the "go/nogo" lexical decision task.

Adult, Good and Poor Reader comparison.

Since the children's results were to be compared with those in Experiment 1, a 5-way ANOVA was conducted with Task type ("go/no-go" v "yes/no") by Word type (Verb v Noun) by Lexical Stress (Iambic v Trochaic) by Frequency (low v High) the within-groups factors, and Reader (Adult v Good v Poor) the between-groups factor. There were no significant 5-way and 4-way interactions. There was a Stress by Frequency by Reader interaction ($F(2,29) = 7.02$, $p = .003$, $\eta 2 = .33$), refer to *Figure 11* below. Experiment 1 has shown that adults responded faster to trochaic items than to iambic items, and it showed the standard frequency effects for trochaic items only.





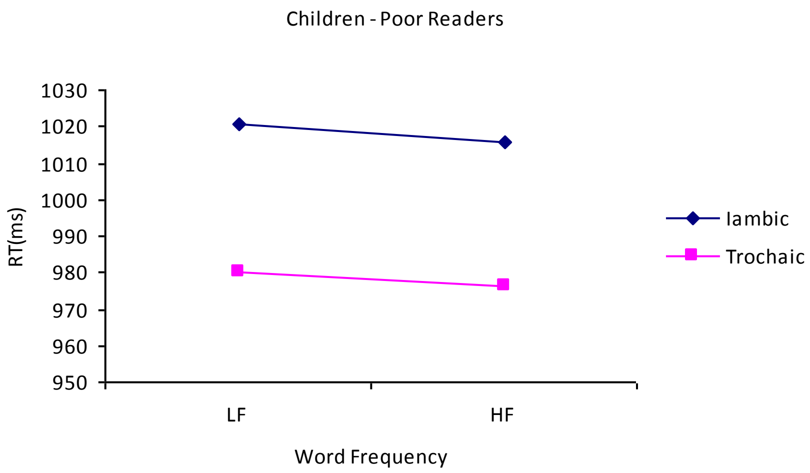
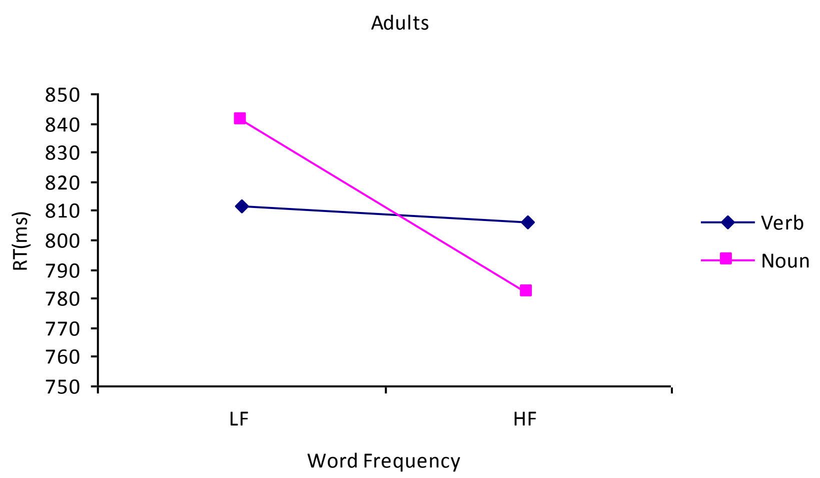


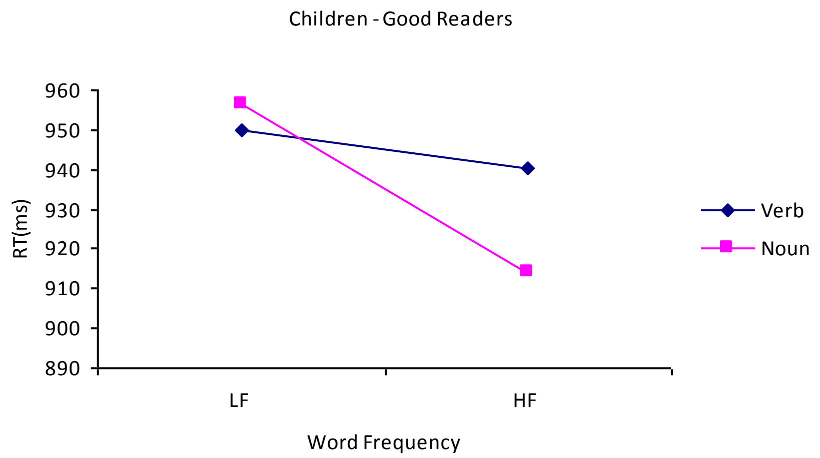
Figure 11: Response Latencies between Lexical stress and Frequency for each level of Reader.

Do good readers mimic the adult processing strategy? Analyses of simple effects showed (refer to *Figure 11*) that good readers had frequency effects in the expected direction for iambic stress ($F(1,29) = 6.12$, $p = .019$, $\eta^2 = .17$) and trochaic stress ($F(1,29) = 15.28$, $p = .001$, $\eta^2 = .35$). This is different to the adult results, which showed frequency effects for trochaic stress only ($F(1,29) = 87.7$, $p < .001$, $\eta^2 = .75$) and not for iambic stress items ($F < 1$).

If poor readers process items more at the pre-lexical level, then they should not show any frequency effects (reflecting lexical access). In fact, poor readers did not show any frequency effects for iambic stress ($F < 1$) nor for trochaic stress ($F < 1$), suggesting that poor readers may use a different strategy to good readers and adults, or frequency does not reliably impact on lexical access for these participants.

Referring to *Figure 12*, there was also a significant Word type by Frequency by Reader interaction ($F(2,29) = 5.57$, $p = .009$, $\eta 2 = .28$).





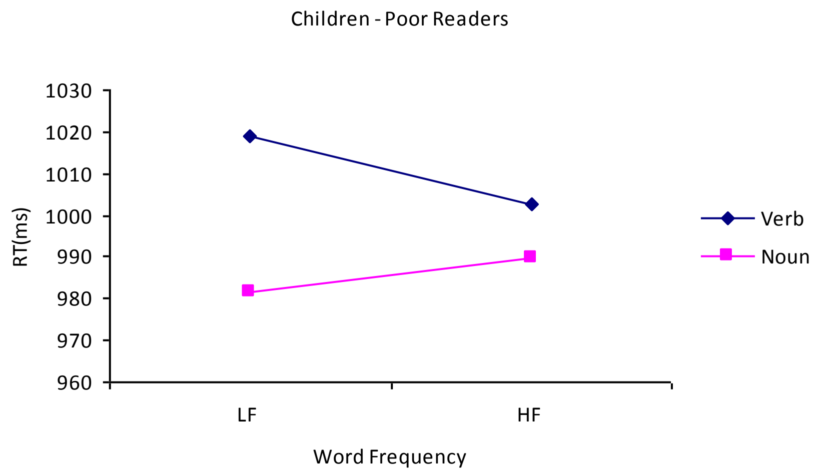


Figure 12, Response Latencies between Word Type and Frequency for each level of Reader.

Analysis of simple effects suggested that adults showed a frequency effect for Nouns only ($F(1,29) = 109.24$, $p < .001$, $\eta^2 = .79$). As expected, good readers showed similar frequency effects for nouns only ($F(1,29) = 32.89$, $p < .001$, $\eta^2 = .53$). Poor readers, again, showed no frequency effects for nouns ($F < 1$) nor for verbs ($F(1,29) = 1.63$, $p = .21$, ns) suggesting that they might use a different strategy in identifying bisyllabic words and processing lexical stress.

Combining the effects in *Figure 11* and *Figure 12*above, the results indicated that adults showed frequency effects for trochaic nouns only. Good readers showed the standard frequency effect for nouns regardless of stress position. Poor readers simply do not show any reliable frequency effects.

Error Analysis

To ascertain if children with poor reading skills will make more errors than good readers and adults, pairwise comparisons between adults, good readers and poor readers were conducted. The analyses showed that good readers made 2.8% more errors than adults (p > .05); and poor readers made 6.5% more errors than adults (p = .002). Poor readers also made 3.7% more errors than good readers (p > .08), which was marginally significant. The only reliable effect was between adults and poor readers, with the latter making more errors.

Another ANOVA was conducted for the Error rate, with Task type ("go/no-go" v "yes/no") by Word type (Verb v Noun) by Lexical Stress (Iambic v Trochaic) by Frequency (low v High) the within-groups factors and Reader (Adults v Good v Poor) the between-groups factors. There were no significant 5-way, 4-way and 3-way interactions. There was a Word Type by Frequency Interaction ($F(1,29) = 16.30$, p < .001, η^2 = .36). Analysis of simple effects showed a frequency effect with low-frequency having 5.6% more errors than high-frequency for nouns only ($F(1,29)$ = 21.05, p < .001, η^2 = .42). The Word Type by Stress Interaction was also significant ($F(1,29) = 9.99$, p = .004, η^2 = .26); where further analysis of simple effects showed that nouns had 5.8% more errors than verbs for iambic items only ($F(1,29) = 12.69$, $p = .001$, $\eta^2 = .30$).

To establish if poor readers showed any frequency effects (see ***Figure 11*** and ***Figure 12***) for nouns and verbs in the error condition, a Post hoc analysis of the Frequency by Stress by Reader interaction was conducted. This analysis showed that good readers had a 4.5% frequency effect for errors for iambic items ($F(1,29) = 5.39$, $p = .027$, $\eta^2 = .16$); and a 3.4% frequency effect for errors for trochaic items ($F(1,29) = 4.87$, $p = .035$, $\eta^2 = .14$). Poor Readers had no frequency effect for errors for iambic stress ($F < 1$) and trochaic stress ($F < 1$).

3.3 Discussion

The hypotheses concerning frequency effects and the sensitivity to lexical stress were supported, with adults showing frequency effects for trochaic items only; good readers matching the adult frequency profile and showing additional frequency sensitivity to iambic items; and poor readers showing no frequency effects neither iambic or trochaic items. The hypotheses concerning latency and error comparisons amongst adults, good and poor readers were partially supported. The adults were faster than the children, supporting Edwards and Lahey's (1993) theory. However, poor readers did not make more errors than good readers did. Two of the hypotheses concerning the differences between "yes/no" and "go/nogo" lexical decision tasks were supported. The "go/nogo" and the "yes/no" lexical decision tasks were not significantly different in respect to response times. The errors rates, however, were different between lexical decision tasks, with the "go/nogo" lexical decision task resulting in fewer errors than the "yes/no" lexical decision task. These results are consistent with the results from Experiment 1. Unlike Experiment 1, the “go/nogo” lexical decision task was not less “noisy” than the “yes/no” lexical decision task. Much of the findings about the differences in lexical decision tasks, variances and frequency effects have already been explained in Experiment 1. The differences between adults, good readers and poor readers are discussed below.

Comparison between children and adults

In this experiment, children’s responses were slower than adult responses, which agrees with the findings of Radeau (1983). One explanation for these differences in response times could be due to longer motor execution times (Kail, 1991); a non-language performance factor. Huttenlocher (1984) assessed differences between children and adults in a primed auditory lexical decision task. She found that children were slower than adults at recognising words. She argued that the delay in processing was attributed to children needing more acoustic input about a word before initiating lexical access. Tyler and Marslen-Wilson (1981), using a word-monitoring, proffered a different explanation to Huttenlocher. They asserted that the children were constrained either by longer lexical access times or by longer motor execution times (Kail, 1991). Edwards and Lahey (1993) argued that proficiency in encoding strategies in adults would influence response times in auditory lexical decision task. Encoding, that is, organizing incoming information in terms of existing knowledge, varies as a function of existing knowledge and adults have had more time to develop better encoding and more efficient processing strategies (Cirrin, 1984). If as Huttenlocher (1984) suggested, children require more input before lexical access proceeds, then trochaic items will produce an advantage and will be processed faster as lexical access starts after the first stressed syllable was processed. If the difference is language related and adults are better at encoding the input then trochaic high-frequency words will have the shortest response latency time, which is indeed the case, as it appears that this encoding strategy is almost automatic. This notion is further explored in Experiment 3.

Error analysis between children and adults

Ramus et. al (2003) suggest that since dyslexic participants have difficulty with reading complex consonant clusters, they possibly have impoverished or "fuzzy" syllable representations in the lexicon. Given these fuzzy representations, Crosbie et al. (2004) suggest that the response latencies between good and poor readers are similar, but there should be an increase in errors that are due to searching and finding underspecified representations. My results did not fully support the Crosbie et. al. claims. Poor readers had similar response latencies and error rates to good readers; but poor readers did make more errors than adults. From the Crosbie et. al. perspective this means that poor readers, relative to adults but not their same aged peers have underspecified mental representations.

Stress and Frequency effects

Trochaic nouns have a first syllable that is used as a trace for lexical access (Cutler, 2008) and, as such, these nouns showed the standard frequency effects where high-frequency nouns had better response latencies than low-frequency nouns for adults and good readers. These noun frequency effects are additive (i.e., no interaction) to the typicality effects, which means that high-frequency typical nouns had faster response latencies compared to low-frequency atypical nouns. Recognising nouns behaved as expected, with high-frequency response latencies being shorter than low-frequency response latencies. The error rates also conformed to the frequency hypothesis, where high-frequency nouns had fewer errors than low-frequency nouns.

The processing of verbs was different; low-frequency typical (iambic) verbs showed faster response latencies than low-frequency atypical (trochaic) verbs (refer to *Figure 10*). According to Mattys and Samuel (2000) iambic words should not show better response latencies than trochaic words, all else being equal. Simply because if (i) stress facilitates lexical access for a specific word, and (ii) in aural words stress is available earlier in trochaic cases than in iambic cases, then (iii) trochaic words should be associated with faster lexical decision times than iambic words. However, the results where the iambic verbs showed better response latencies agree with findings reported by Arciuli and Cupples (2004). They found differences between atypical and typical items in the lexical decision task (Experiment 2), with iambic verbs and trochaic nouns showing better response latencies than trochaic verbs and iambic nouns. Their results suggested that there are other factors, such as typicality, that mediate word recognition.

Previous research has shown an interaction between typicality and frequency, with low-frequency typical items showing better response latencies than low-frequency atypical items (Colombo, 1992). This effect can be explained using the race-model, where two parallel frequency and typicality processes race one another in word identification. It would be expected that frequency would pre-dominate for high-frequency items (Seidenberg et al., 1984). However, the typicality process would pre-dominate for low-frequency items in these experiments, hence low-frequency iambic verbs, which are typical in its class, showed better response latencies than low-frequency trochaic verbs, which are atypical.

This race model may explain why poor readers did not show any frequency effects for iambic and trochaic items. If poor readers relied more on phonological cues like lexical stress, then the typicality processes could mask the frequency effects. Waters, Seidenberg and Bruck (1984) suggested that reading skills appear to mimic the frequency variable; that is, the less skilled the reader the more likely it is that phonological cues (Monaghan, Chater, & Christiansen, 2005) are activated prior to word recognition. Hence, poor readers are more sensitive to and rely more on lexical stress processing.

Davis and Kelly (1997) also proffered that, in the absence of a large vocabulary, poor readers would rely more on word stress cues to make grammatical assessment of verbs and nouns. Knowing that most verbs having rising pitch and nouns have descending pitch, poor readers would first focus their attention implicitly on the words stress cues (this assertion is further explored in Experiment 3). Murray and Forster (2004) contended that other factors such as concreteness, word length, typicality and consistency, homophony, number of meanings and neighbourhood density also influence word recognition but show effects at low frequency ranges only. Thus, in this experiment and Experiment 1, low-frequency typical verbs were recognised faster than high-frequency atypical verbs.

Poor readers did not show any frequency effects. Word frequency effects are commonly taken as evidence that processing is sensitive to lexical structure (Borowsky & Masson, 1999) in a lexical decision task. Not showing any frequency effects suggests that poor readers did not transverse the lexicon in frequency order for iambic as well as trochaic disyllabic words or they could have processed the items phonetically as described in the race model above.

Pitting the poor reader's sensitivity to suprasegmental skills against the skills of the good reader is the focus of Experiment 3, which is a speeded grammatical categorization task. The participant must categorize verbs and nouns using typical disyllabic verbs and typical disyllabic nouns only, through either attending to the stress properties (ascending or descending pitch) of the word or on the semantic properties of the word (eg. *Is it an action or a thing?*).

Summary and rationale

The rationale for this next experiment is, if one assumes a temporal order in word recognition to consist of acoustic/phonetic processing, then lexical access and then semantic processing. Moreover, if the verbs or nouns presented could be categorised on their acoustic (e.g., rising and falling pitch) or semantic (e.g., Is it a thing or action?) attributes, then those adopting an acoustic processing strategy would show shorter response latencies but no frequency effects.

The results of this Experiment 2, suggest that poor readers may be more sensitive to the suprasegmental cues of the words. Good readers, who may rely less on suprasegmental features of the word, may process the presented items at the semantic level. This semantic access to categorize the grammatical class may take longer and thus disadvantage the good reader whereas poor readers could make a decision based on acoustic cues. In Experiment 3, participants will be given the option to categorise typical nouns (e.g Kitchen) and typical verbs (e.g Attack) using either pre-lexical processes alone or pre-lexical and semantic processes.

4 Experiment 3 – Speeded categorization task

The aim of this experiment is to assess if poor readers would utilize their sensitivity to stress cues to their advantage in a categorization task.

This experiment assesses whether good and poor readers rely on lexical stress processing or a combination of lexical stress and semantic/syntactic processing to classify typical disyllabic verbs (e.g., attack) and nouns (e.g., kitchen) in a speeded grammatical categorization task. Poor readers could use their sensitivity to lexical stress to their advantage when presented with a choice to use either suprasegmental features or, suprasegmental and semantic features to categorise words as either verbs or nouns. Why would poor readers rely more on a suprasegmental processing strategy to categorise the words? Mattys, White and Melhorn (2005) asserted that in the absence of other cues and context, the spoken word recognition process relies more on suprasegmental processing strategies. Given that words are presented without context, one expects that poor and good readers could process items at the suprasegmental level as they would normally do in pursuit of an explicit goal. But good readers may not attend too much to the suprasegmental features, because phonological information is less implicated in the lexical access process of the fluent English reader (Cutler & Pasveer, 2006; Stanovich, 2000). The claim here is that the poor reader has conscious access to stress information, and so can use that to achieve the goal of categorising something as a noun or verb on basis of its lexical stress (assuming only typical items are used). The good reader may not consciously rely on this (intentional) access, and so relies on the information provided by the lexical entry.

Monaghan, Chater and Christiansen (2003; Monaghan et al., 2005) reviewed the phonological and distributional cues (e.g., phonotactics) that are useful in determining the grammatical class of a word. They claimed that nouns and verbs cluster together in phonological space: typical disyllabic verbs have ascending pitch and disyllabic nouns have descending pitch. Therefore, the classification of typical verbs or nouns could be achieved by attending to suprasegmental properties of the word only, if the listener has a proficiency in consciously identifying suprasegmental features of words.

How would we know that poor readers are relying more on suprasegmental features for verb and noun classification?, We have already seen in Experiment 2 that poor readers showed no evidence of frequency effects when accessing the lexicon in a lexical decision task. In the categorization task, the participants categorize items before the lexicon is accessed if they are doing it based on pre-lexical information. In this experiment, if poor readers categorise words on their suprasegmental features only (eg., pitch), then their classification of these words should not show any frequency effects, as it does not utilise the lexicon and later semantic processing. Thus, when presented with typical trochaic nouns (eg. KITCHen) or typical trochaic verbs (eg. aTTACK), the poor reader could categorise the items using their suprasegmental features without considering whether one item is a “thing” or an “action”.

Assuming a temporal order to spoken word processing, the component processes include a separate pre-lexical and lexical level processes (Frauenfelder & Tyler, 1987; McQueen, Norris, & Cutler, 2006). Therefore, to identify a typical disyllabic verb or noun, the proficient English listener would first process the item at the segmental level, access the lexicon, then categorise the words based on their semantic properties. Given access to the lexicon, it is expected that good readers would show frequency effects.

This experiment is a “go/nogo" word type categorization task, because its showed less errors than the “yes/no” lexical decision task in Experiment 1. The lists of stimulus items will be typical nouns with descending pitch and typical verbs with ascending pitch. Although the list consists of verbs and nouns, it also consists of words with ascending and descending pitch; and if some of the participants are sensitive to these variations in pitch, they may rely on a strategy based on pitch variations to their benefit. Pitch is a suprasegmental feature, and English listeners generally do not attend much to these features in word recognition (Cutler & Pasveer, 2006; Stanovich, 2000). However, it appears that a sub class of English listeners, poor readers and those with limited vocabularies, do attend to these suprasegmental features (Davis & Kelly, 1997).

As reported earlier, research indicates that children with dyslexia do equally well or better at discriminating acoustic variants within a group of allophones (Serniclaes et al., 2001; Werker & Tees, 1987). The sensitivity to distinguishing between typical disyllabic verbs and nouns can be based on suprasegmental information alone without recourse to allophonic distinctions. Although no assessment was made for dyslexia amongst the participants, it was expected that poor readers, as defined by the lower 25 Percentile scores in a TOWRE test, would also be sensitive to variation in pitch in typical bisyllabic verbs and nouns. *It is* *therefore hypothesized that poor readers are more likely to use a suprasegmental strategies, as suggested in part by Davis and Kelly (1997) and Serniclaes and colleagues (2001). As such, poor readers will be faster at word categorization than good readers. Good readers will rely less on suprasegmental features (Cutler & Pasveer, 2006) and focus on segmental features to process the items at a lexical level, thus showing frequency effects whereas poor readers will not show any frequency effects.*

4.1 Method

Participants:

Eighteen children from a local Catholic School in the outer Eastern suburbs of Melbourne took part in this experiment. These participants did not participate in any of the previous experiments. Participants reported normal hearing. There were 9 males (*M* = 11;5 *range 10;2-12;5*) and 9 females (*M* = 11;6 months, range 10;4-12;6). They all reported English to be their first language. The poor readers were identified as those children scoring below the 25 percentile of the TOWRE test.

Table 8

Mean scores and (standard deviation in parentheses) for good and poor readers as identified by the TOWRE test

	Good Reader	Poor Reader
Number of participants	11	7
Age(SD)	11.7 (0.7)	11.2 (1.1)
TOWRE Sight Word(SD)	103.7 (9.2)	89.4 (5.3)
TOWRE Phonemic decoding (SD)	108.5 (11.9)	79.9 (7.0)

Total TOWRE (SD)	65.54 (23.6)	12.29 (7.8)

Material

The items consisted of typical nouns (eg. KITCHen) and typical verbs (eg. aTTACK). The word list consisted of 40 typical items (refer to appendix B) which included: 10 high-frequency nouns, CELEX spoken word frequency (M = 57.7, SD = 36.6); 10 low-frequency nouns CELEX spoken word frequency (M = 3.3, SD = 2.6); 10 high-frequency verbs CELEX spoken word frequency (M = 66.6, SD = 27.9); and 10 low-frequency verbs CELEX spoken word frequency (M = 2.2, SD = 1.9)

The cut-off spoken word frequency ranges were as follows: for *low-frequency* trochaic nouns (0.1-9) and iambic verbs (0.1-6); and, *high-frequency* trochaic nouns (30-96) and Iambic verbs (24-76), High-frequency verbs and nouns showed no significant difference ($F < 1$) and low-frequency verbs and nouns showed no significant difference ($F(1,18) = 1.24$, $p = .28$, $\eta^2 = .07$). The stimulus items were recorded at 44.1 KHz 16 bit, and the average file lengths[4] for nouns was M = 59527 bytes (SD = 7163), and for verbs was M = 70425 bytes (SD = 6970). The file lengths for nouns were shorter than verbs ($F(1,38) = 23.78$, $p < .001$, η^2 =.39).

Procedure

Participants were tested individually in a quiet room at school where the children were always in full view of staff. Each participant was tested on a laptop computer. Sound was relayed at a comfortable loudness through volume adjustable earphones. During the trial period, the participant was allowed to vary the volume

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[4] Second = file length divided by 44.1 kHz; e.g. 59527 bytes/44100 = 1350ms

to suit their hearing. Participants were asked whether they knew the difference between a noun (a thing) and a verb (an action word). All participants knew the difference. Participants were asked to listen to practice words, where the nouns had trochaic stress and the verbs had iambic stress. They were instructed that they could make a noun-verb categorization by also focusing on the word's stress pattern. Participants were told that disyllabic nouns sounded louder at the beginning of the word and verbs sounded louder at the end of the word. There were two sessions: one set of trials tested for nouns and the other set of trials tested for verbs, using the same stimulus items. Each session took about 1-2 minutes for the child to hear and respond to 40 items. Each list of items was scrambled, thus giving each participant a unique order of 20 trochaic nouns and 20 iambic verbs. The participants were instructed as follows:

You will hear a word. Your task is to decide if the word is a noun (or verb). If the word is a noun (or verb), press the index finger button on the game pad of either hand as quickly as possible. If the sound is not a noun (or verb), do not press any buttons on the game pad. A smiley face ☺ will tell you if you made the correct decision. A frowning face ☹ will tell you if you made the wrong decision.

The material was presented over two sessions, with half the participants starting with nouns first and the other half starting with verbs first. If the session was for detecting verbs, then the participant needed to respond to verbs only, otherwise the participant ignored the items. The same process was followed for nouns. The interval between sessions sometimes spanned a few days and in some instances a few weeks. The maximum time lapse between two sessions was a month. The shortest interval between sessions was 5 minutes.

The participant was placed at a comfortable level in front of the PC. The participant first completed a practice run. When the participant was not confident about the procedure, the practice run was repeated. The practice run consisted of two items from each condition. The computer ran the DMDX software by Forster and Forster (2003). The Logitech game pad was setup in DMDX to start presenting the first stimulus item in the session when the participant pressed the right hand thumb button. The left and right hand buttons on the game pad were programmed to record the “yes” answer. For the “no” answer the participant had to ignore the right and left buttons, that is, not make a response. The trial would start with a ‘+’ sign presented for 500 ms in the middle of the screen. Thereafter the participant would hear the stimulus item. The next trial started immediately after the response. When there was no response on a target item, the next trial would start 2000 ms after the onset of that item and the trial was counted as an error.

4.2 Results

Response latencies and error rates were calculated using response times (RTs) between 250ms and 1500ms. Values outside of this range were not included as they were interpreted as premature responses or otherwise not on task. Using this range of response times resulted in no respondent being excluded from further analysis based on an error rate exceeding 20%, and data trimming at two standard deviations. Initial analysis showed no effects for the order in which noun and verb identification was conducted ($F(1,16) = 1.29$, $p = .27$) and the results were combined.

An ANOVA was applied to the RTs and error rates relative to the following factors; Word Type (verb vs. noun) and Word Frequency (high vs. low frequency) were within-participant factors, while Reader (good vs. poor) was the between-participant factor. Refer to mean RTs in Table 9 below.

Table 9

Response time (RT) and percentage error (Err) results between good and poor readers for typical nouns and typical verbs. The standard deviations are in parentheses.

Reader		Noun		Verb	
		HF	LF	HF	LF
Good					
	RT	1116 (87)	1145 (101)	1167 (137)	1181 (91)
	Err	14.6 (10.0)	13.4 (10.1)	14.2 (13.5)	22.3 (11.3)
Poor					
	RT	1043 (96)	1015 (136)	1035 (100)	1001 (150)
	Err	9.3 (10.2)	16.2 (20.6)	8.3 (5.8)	12.1 (11.0)

Response latency: If poor readers were using suprasegmental properties from the pre-lexical level to assists with categorization, then poor readers should show shorter response latencies. There was a significant main effect, poor readers were 129 ms faster in response latency than good readers ($F(1,16) = 8.87$, $p = .009$, $\eta^2 = .36$). This is illustrated in *Figure 13*, below.

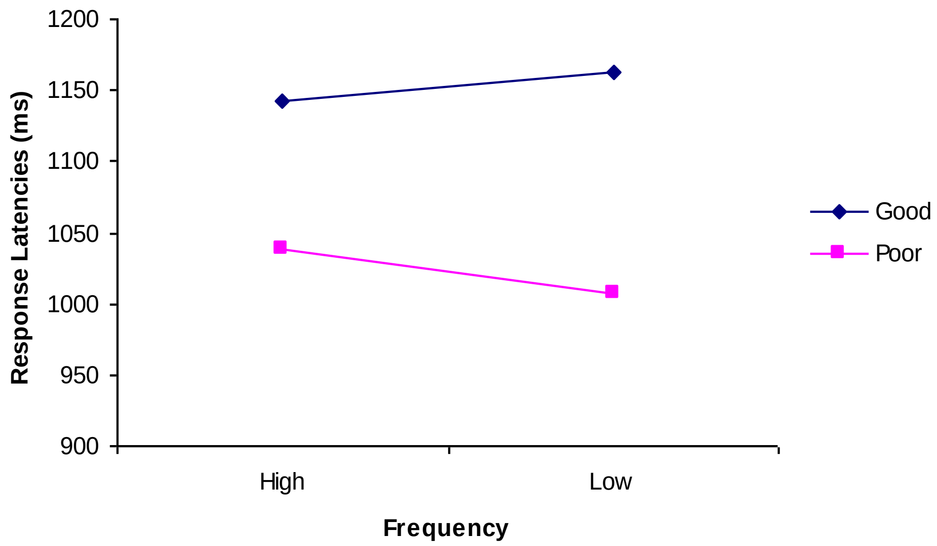

*Figure 13***,** Frequency response latencies between good and poor readers

There was also a significant Word Frequency by Reader interaction ($F(1,16) = 4.55$, $p = .049$, $n^2 = .22$). Simple contrasts showed that good readers showed a frequency effect ($F(1,10) = 4.80$, $p = .05$, $\eta^2 = .32$) with high-frequency items having faster response latencies than low-frequency response latencies. Poor readers showed no frequency effect ($F < 1$). No other latency results were significant.

Errors: In the previous experiments, atypical items always elicited more errors; however, this experiment did not have any atypical items and it was therefore expected that the errors for typical nouns and verbs would be minimal or the same. The results showed no difference in verb and noun error rates ($F < 1$) for poor readers. Frequency effects are robust and, as expected, the results showed that low-frequency items had more errors than high-frequency items ($F(1,16) = 6{,}73$, $p = .02$, $\eta^2 = .30$) for good readers. A further analysis of the simple effects showed this frequency effect was only for typical verbs ($F(1,16) = 6.00$, $p = .026$, $\eta^2 = .27$) for good readers.

Speed accuracy trade-off: Analysis of speed accuracy trade-off revealed a significant correlation between response latencies and errors for good reader responses to verbs ($r(9) = .73$, $p = .01$). This positive correlation suggests that there was no speed accuracy trade-off: as errors increased so did response latencies. No other correlations between response latencies and errors were significant.

4.3 Discussion

The results support the hypothesis that poor readers were more sensitive to suprasegmental cues and were faster at recognising typical nouns and verbs when compared to good readers. Most adults (and assumedly good readers as well) rely less on stress cues and tend to use more phonotactics to recognise words (Morgan, 1996b). On the other hand, good readers may have been constrained by an "automaticity" strategy (Samuels, 1994); that is, good readers automatically accessed the lexicon to match their input against their cluster of verbs or nouns (Monaghan et al., 2005). For example, poor readers could have focused just on the iambic or trochaic acoustic patterns of the word; that is, they knew that typical nouns have descending pitch and typical verbs have ascending pitch. This assertion is further supported by the frequency effect that was only prevalent for good readers, suggesting that good readers accessed their lexicons during word recognition. Poor readers on the other hand did not show any frequency effects. The lack of frequency effects in this case suggests that poor readers did not access their lexicons to make decisions regarding word categorization.

When poor readers hear the first word, they listen for variation in pitch. Poor readers could have listened for an ascending pitch (when categorising verbs), and if they detected a descending pitch relative to the first syllable, then the item was categorised as a verb. Given their sensitivity to assess pitch variation, they could have begun to categorise the words as either verb or noun, which resulted in much shorter response latencies compared to good readers. Poor readers could have used a similar strategy when they categorised nouns.

Furthermore, items in the list were constructed to facilitate “extrinsic” factors, which is where the composition of the list affects some of the results (Connine et al., 1993) so that the listener can also employ strategic processes (McQueen & Sereno, 2005) rather than lexical access alone. If the listener is sensitive enough to be conscious of the slight variations in pitch, they could categorise items much earlier at the acoustic stage. It appears that poor readers in this experiment were sensitive to pitch variation and processed the items according to each words pitch pattern.

Strategic processes masked frequency effects: frequency modulated access competes with other processes to identify words. Let’s say that all the words in a lexical decision task start with the consonant cluster /str/ and all the non-words do not start with /str/. Then, irrespective of the presentation of the stimulus items and their respective frequencies, the listener would eventually use the word initial /str/ consonant cluster to identify the words. Likewise, when words are presented where the nouns have descending pitch and verbs have ascending pitch, then, as a strategy, the listener could use that information to categorise nouns, rather than use the noun's classification as a "things". In this experiment, the "extrinsic" factor (Connine et al., 1993) of pitch variations within the first and second syllable provides sufficient information for "another means" to assist in the speed of categorization, rather than frequency. Since there was no frequency effect evident for poor readers, one could assume that the poor readers utilized their sensitivity to lexical stress to categorize the words.

Good readers, again, processed the items at the segmental level and were less conscious of the suprasegmental features (Cutler & Pasveer, 2006). In this experiment, the good and poor readers were given a choice to use either suprasegmental features or, suprasegmental and semantic features to categorise words as either verbs or nouns.

In summary, in these last three experiments, the participants had to make auditory lexical decisions and auditory categorization decisions when presented with a single spoken word or non-word at a time. Individual differences suggest that adults rely less on suprasegmental features and may use phonotactics, although this was not directly tested. Adults were also faster than children at word recognition. However, children with good reading skills appear to have the same profile to the adult's word recognition skills. Poor readers made more errors than adults and appear to rely more on suprasegmental information in word recognition and classification. Adults and good readers had a trochaic preference that was mediated by word frequency. Poor readers thus far did not show any frequency effects in the lexical decision task and in the categorization task.

The next section investigates the relationship between good and poor readers and their ability to process two stressed items simultaneously. One way to ensure that both good and poor readers attend to suprasegmental features is to use minimal pairs (words like RECord and reCORD). For example, the word "record" is a noun when the stress is on the first syllable and it is a verb if the stress is on the second syllable. This approach forces good readers to also attend consciously to lexical stress differences between nouns and verb.

Experiment 4, gives the readers a choice to use acoustic/phonetic information but in a task that requires more cognitive resources (holding two items in memory at one time), which might create a bias towards processing pre-lexical information.

5 Experiment 4 – Temporal order judgement Task

The aim of this experiment is to assess if good and poor readers would utilize their sensitivity to stress cues in a temporal order task using minimal pairs as stimuli.

Why is phoneme awareness difficult for some children to achieve? Studdert-Kennedy (2002) suggests that a deficit in phonemic awareness stems from poor speech perception, which results in 'fuzzy' or 'underspecified' lexical (and so phonological) representations. He proposes two hypothesis concerning the nature of these deficits in speech perception; a speech-specific hypothesis (Liberman, 1998) and general auditory hypothesis (Tallal, Miller, & Fitch, 1995).

The general auditory hypothesis by Tallal and colleagues (Reed, 1989; Tallal, 1984a; Tallal, Stark, & Mellits, 1985) holds that poor readers have a problem with general auditory processing, including artificial sounds, in temporal order judgment tasks (refer to description below). Presenting artificial tones may cause poor readers some difficulty as it has been reported that processing rapid temporal stimuli disrupts the development of representative phonological codes in memory (Reed, 1989; Tallal, 1984a) and poor readers have difficulty processing items that are presented with a very short inter-stimulus interval (Tallal, 1984b). There are detractors (Richardson, Thomson, Scott, & Goswami, 2004) of this general auditory hypothesis on the grounds that

> "positive findings are difficult to replicate, that only sub-groups of dyslexics are affected, that when positive relationships are found they are more robust

> in control groups, and that when auditory deficits are found they tend to be small and cannot easily explain the large phonological deficits observed" (p 216)

Studdert-Kennedy (2002) criticises this general auditory hypothesis, as he asserts that artificially created tones have no true linguistic relationship to phonetic (speech-specific) word perception. In particular, processing artificial sounds is not true of a group's ability to process spoken words, as artificial stimuli do not tap the proper spoken word phonological processes. Much of the '*rapid processing deficit' literature* focuses on performance of processing non-speech sounds and relate these to speech sounds. However, as Rosen (2003) reported, there is no clear relationship between speech deficits and non-speech processing. There are three cautions to this reliance and inference on non-speech sounds (Studdert-Kennedy, 2002), and they are: first, the effects attained in non-speech experiments are correlational. A causal role cannot be established only by showing equivalent deficiencies in perceiving both speech and an acoustically matched non-speech control. Second, the experiments (Kinsbourne, Rufo, Gamzu, Palmer, & et al., 1991; Reed, 1989; Tallal, 1980; Tallal et al., 1995; Tallal & Piercy, 1973) that focus on reaction time to pure tones etc. have no bearing on speech perception. Ramus et. al (2003) assessed dyslexic university students and found that they too performed poorly on discrimination tasks using non-speech sounds. However, when they tested participants using speech sounds, none of the results of speech sounds discriminated between dyslexic and non-dyslexic students. Three, temporal order judgements may vary with cognitive capacity such as attentiveness or intelligence (Studdert-Kennedy, 2002)

On the other hand, the speech-specific hypothesis (Liberman, 1998) proposes that the deficit is in the phonetic transformation from analogue neural response patterns to digital lexical/phonological representation. One of the issues that affect poor readers is low perceptual performance on human speech under speeded conditions. Studdert-Kennedy (2002) also supports this notion that poor reader's reading performance stems from "difficulty in discriminating and *identifying phonetically similar* (although *phonological contrastive*) syllables under pressure" (p.11).

Experiment 3 showed better response latencies for poor readers because the task demands were simple and allowed for the recruitment of strategic processes and readers had the choice to process the items phonetically or segmentally. This experiment requires the readers to categorise verbs and nouns, in much the same way as they did in Experiment 3. To force readers to process lexical stress consciously, where they must attend to lexical stress, they'll be presented with minimal contrastive pairs, which are two words (a pair) which can be told apart (contrasted) by the smallest (minimal) difference. For example, the minimal pair RECord (noun) and reCORD (verb) are contrasted by the syllabic stress placement on each alternate syllable of the words. In Experiment 3, poor readers appeared to show a preference for using acoustic processing in categorising words. This does not mean that poor readers are better at processing acoustic cues; rather it suggests that when given the choice between acoustic processing and semantic processing (is it a verb or noun) in the categorization task, poor readers chose an acoustic strategy, by focusing on pitch. In this experiment, both poor and good readers have to engage in acoustic processing to categorise the nouns and verbs in a temporal order judgement task using minimal pairs; and like Experiment 3, participants have to listen consciously for rising and falling pitch to make a judgment.

In this experiment, participants will complete a temporal order judgment task where the stimulus items are natural speech sounds. Participants are asked to make judgements about presented stimuli by pressing two response buttons in a certain order. Generally, when the Inter-Stimulus-Interval (ISI) is short (5ms) participants may have difficulty distinguishing between the two stimuli. ISIs longer than 40 ms is normally considered reasonable whether the stimuli are visual or auditory (Kanabus, Szelag, Rojek, & Poppel, 2002). In this experiment, the ISI will be set at 50ms. The stimulus items are minimal pairs and participants have to decide if it has rising pitch or falling pitch

To avoid Rosen's (2003) pitfalls and heed Studdert-Kennedy's (2002) cautions, this experiment ascertains the reader's ability to identify grammatical class when presented with *spoken disyllabic minimal pairs*, which are *segmentally similar* and which differ only in their *phonological contrastive* stress location. The experiment assesses the readers' ability to hold two contrastive pairs in memory and to decide, whether the first or second item is a noun or a verb. There is a certain amount of being "under pressure" as Studdert-Kennedy (2002) asserts; but the participants were given extra time if they did not fully detect the difference in the first trial, reducing the amount of pressure. Ramus et. al (2003) findings suggest that if non-artificial stimuli are used there should be no difference in performance between poor and good readers; therefore *its hypothesised that poor readers would not make more errors nor would they be slower than good readers*.

In Experiment 3, it became obvious that the readers used a different strategy to solve the categorization task. In this task, both readers must attend to the suprasegmental features to distinguish minimal pairs. However, when processing items at the acoustic level or when certain items force an acoustic strategy, Monaghan and colleagues (Monaghan & Ellis, 2002; Monaghan et al., 2003) suggested that iambic items are processed favourably. *It is therefore hypothesised that both readers would be faster at recognising iambic items than trochaic items.* This experiment requires mostly pre-lexical processing. To classify the minimal pairs as a verb or noun, the listener has to attend to the ascending or descending pitch respectively of the stimulus items. It is therefore hypothesised *that if all readers use acoustic pre-lexical processes then there should not be any frequency effect.*

5.1 Method

Participants

Eighteen children from a local Catholic School in the outer Eastern suburbs of Melbourne took part in this experiment. Most of them participated in Experiment 3. There were 9 males (*M* = 11;5 *range 10;2-12;5*) and 9 females (*M* = 11;6 months, range 10;4-12;6).

Table 10

Age and mean standardized scores for children that are good and poor readers as identified by the TOWRE test. Standard deviations are in brackets.

	Good Reader	Poor Reader
Number of participants	11	7
Age(SD)	11.8 (0.8)	11.2 (1.2)
TOWRE Sight Word(SD)	105.4 (9.3)	90.8 (5.4)
TOWRE Phonemic decoding (SD)	112.1 (8.2)	82.6 (8.2)
TOWRE (SD)	73.0 (18.7)	16.7(11.0)

Material

The items consisted of 10 high-frequency and 10 low-frequency noun-verb *spoken disyllabic minimal pairs* (see Appendix C). The cut-off spoken word frequency ranges were as follows: for *Low-frequency* items (0.56-3.8), and *high-frequency* items (30-79). High frequency items had an average spoken CELEX value of 45.31 (SD = 18.5) and low-frequency items had an average spoken CELEX value of 1.30 (SD = 2.5). The words were recorded at 44.1 kHz and the comparison of the file lengths for nouns were M = 68481 bytes (SD = 11990) and for verbs were M = 71058 (SD = 10440). The file lengths were equivalent as there was no difference in file sizes between verb and noun stimulus sets (F < 1).

Procedure

This is a temporal order judgment task. The participant will hear a verb-noun or noun-verb combination, and depending on the request whether it was a verb or noun, the participant would respond to indicate the first or second. The participant was placed at a comfortable level in front of the PC. The participant first completed a trial run. The trial run consisted of two separate trials from each condition. When the participant was not confident about the procedure, the whole trial session was repeated. The computer ran the DMDX software by Foster and Forster (2003). The trial would start with a '+' sign presented for 500 ms in the middle of the screen. Thereafter the participant would hear the first verb-noun pair. The next trial started immediately after the response. If the participant did not make a response after 5000 ms, s/he was prompted to press their thumb button and to repeat the trial. The verb-noun pairs were presented at an ISI of 50 ms, with the response latency starting immediately after the second word offset. The left hand button was programmed to mean "first" and the right hand button was programmed to mean "second". No feedback was provided.

There were two sessions, one for identifying verbs and another for identifying nouns. Each participant either started with a noun or verb classification first. Each task took about 3 minutes, maximum. Each list of items was scrambled, thus giving each participant a unique order of the trials. Participants were told that verbs and nouns sound differently, for example seCOND (verb) and SEcond (noun). Verbs have louder sound on second syllable and nouns have louder sound on first syllable. Participants were tested individually in a quiet room at school where the children were always in full view of staff. Each participant was tested on a laptop computer. Sound was relayed through earphones at a comfortable loudness. Participants were instructed as follows:

You will hear two similar sounding words. Your task is to decide which

> word is a noun, the first word or the second word. If the first word is a noun press the left button on your game pad, if the second word is a noun press the right button on your game pad. If you want to hear the word again, press your thumb button on the game pad.

For the verb trial, the participant got the same instruction asking them to listen for verbs only.

> You will hear two similar sounding words. Your task is to decide which word is a verb, the first word or the second word. If the first word is a verb press the left button on your game pad, if the second word is a verb press the right button on your game pad. If you want to hear the word again, press your thumb button on the game pad.

The material was presented over two sessions, spanning a few days in some instances a few weeks. The maximum time lapse between two sessions was a month.

5.2 Results

Response latencies and error rates were calculated. Given that most response latencies were within the 250 ms to 2800 ms range, items were winsorised; that is some outlier items were replaced by values at the 95 percentile. Very few participants requested a retry, of the 360 responses made by the 18 participants, only 18 (5%) of responses were retried. If they answered correctly on the retry, the participant got a correct response, except that the response times were winsorised with other outliers. Using this range of response times resulted in no respondents being excluded from further analysis. There were no order effects and the response latencies and error results were combined and listed in Table 11 A 3-way mixed design ANOVA was conducted with Word Type (verb v noun) x Word Frequency (High v Low) as within-participant factors and Reader (good v poor) as between-participant factor.

Table 11

Response times (RT) and percentage errors (Err) between good and poor readers for typical nouns and typical verbs. The standard deviations are in parentheses.

Reader		Word			
		Noun(trochaic stress)		Verb(iambic stress)	
		HF	LF	HF	LF
Good					
	RT	1639 (291)	1585 (209)	1453 (200)	1431 (198)
	Err	4.0 (1.5)	5.0 (1.7)	3.9 (2.0)	4.0 (2.3)
Poor					
	RT	1564 (502)	1606 (449)	1346 (191)	1418 (244)
	Err	5.0 (1.4)	4.4 (1.3)	5.4 (0.8)	4.4 (1.5)

Response times: The 3-way interaction between Word Type, Word Frequency and Reader was not significant ($F < 1$). All 2-way interactions were also non-significant ($F < 1$). There was no response latency difference between good and poor readers ($F < 1$). There was, however, a main effect for Word Type, iambic stress was recognised 186 ms faster than trochaic stress ($F(1,16) = 6.03$, $p = .026$, $\eta^2 = .27$). There were no other significant effects, including no Word Frequency effects for Good Readers (F < 1) and Poor Readers (F < 1).

Errors: No other main effects or interactions were significant.

5.3 Discussion

The results support the hypothesis about good and poor readers having equal latency scores in categorizing trochaic and iambic items in a temporal order judgement task using minimal pairs. There were no frequency effects, supporting the notion that good and poor readers did not process these items at the lexical level. Moreover, poor readers did not make more errors than good readers did. Iambic items were perceived better than trochaic items. These findings are discussed below.

Experiment 3 has shown that poor readers favour a pre-lexical processes strategy to categorising a verb or noun when presented with a single stimulus items and using a “go/nogo” lexical decision task. In this experiment, poor readers did not process pre-lexical items any different to good readers, this indifference supports the finding of Studdert-Kennedy, 2002 when using non-artificial stimuli. And, as Ramus et. al (2003) have predicted, when poor and good readers are tested on speech specific stimuli, there are no differences in performance and error rates.

The results suggest that these children favoured an iambic strategy. Lewis, Antone and Johnson (1999) proffered some reasons for children focusing on the word final syllable could be either as a result of a learning principle to pay attention to word final syllables (Slobin, 1985), or recency effects (Echols & Newport, 1992). Lewis et al. argued that

> "Weakly stressed syllables and word-initial syllables would not be included in the child's representation of multisyllabic words because of a tendency to extract only strongly stress or word-final syllables or both. Syllables that are absent from a child's production are hypothesized to be absent from the child's phonological representation of the word" (p. 46)

The most compelling argument for an iambic bias for all children comes from Monaghan, Chater and Christiansen (2003) who reviewed cues that are useful in determining the grammatical class of a word. They focused on phonological cues and distributions cues that "typically" identify a word's grammatical class. Briefly, *distributional cues* are positional; for example, any word that replaces the <gap> in the sentence fragment "The <gap> is/was/are/were good" has to be a noun; e.g., "The *coffee* is good". *Phonological cues* consist of phonological variables where nouns tend to have stress on initial syllables and verbs have stress on the second syllable. There are 16 phonological cues and, for a description of each cue, see Monaghan, Chater and Christiansen (2005). They "hypothesized that the extent to which a word shares phonological cues with other words in the same syntactic category to which it belongs would influence the response latency to that word" (Monaghan et al., 2003, p. 811). For example, if phonological cues are used to categorise an item then the more cues that are satisfied, the more "typical" the item is of its class. A question they asked was which of these cues have greater influence in determining grammatical class. They entered all these cues into a hierarchical regression analysis, and found *phonological cues,* which includes lexical stress, to be an important cue for verbs but not for nouns. Therefore, items with an iambic structure will have greater influence in word categorization, when the categorization depends more on phonological cues. Hence, a categorization task of spoken noun-verb *disyllabic minimal pairs*, and the distinct phonological selection would favour iambic words.

Experiment 3 also suggests that good readers do not attend much to suprasegmental features, rather good readers focus on segmental features (Cutler, 2008). Hence, asking good readers to categorise a word relying on suprasegmental features is almost a regression, when good readers and adults lose the ability to discern contrasts. This does not mean that good readers and proficient adult readers do not have the ability to use suprasegmental information explicitly; rather they would prefer to use phonotactics.

Although there was no difference in performance between good and poor readers, they could have used different strategies, which are further explored in Experiment 5. The selection of the noun or verb is essentially a binary task and therefore one could accomplish the task by either listening for iambic stress only in both verb and noun selection cases. For example, if poor readers listened for iambic stress and the task was to categorize verbs, then if the first item of the spoken noun-verb *disyllabic minimal pairs* did not match, then the correct item must be the second item. Likewise, if good readers had a trochaic bias and the task was to categorize verbs, then if the first item of the spoken noun-verb *disyllabic minimal* pair was not a verb then the correct item must be the second item. No frequency effects were encountered. Like the previous experiment, acoustic processes were used to confirm verb or noun status, and none or very little lexical access and semantic processes were needed to identify verbs and nouns. One could argue that good readers may have used phonotactics, if so, they would have shown frequency effects as per the segments frequency effects (Vitevitch & Luce, 1999), Another reason for not having had a frequency effect might be the long response latencies. Most of the response latencies were more than 1000ms (refer to Table 11), suggesting that the tasks may not have been performed at the pre-lexical. However, these longer response latencies could have masked the frequency effect.

In summary, this experiment showed that there was no latency difference when poor and good readers process disyllabic spoken noun-verb minimal pairs in a temporal order judgment task using normal speech sounds. This was to be expected as previous research (Franck Ramus et al., 2003; Rosen, 2003; Studdert-Kennedy, 2002) has indicated that temporal order judgment tasks show differences between readers for non-speech stimuli but not for speech sounds. All the sounds in these experiments were created by the human articulatory tract. Experiment 3 showed that poor readers chose an acoustic strategy to categorize words and might not have been better than good readers. Therefore, when good readers were “forced” to attend to suprasegmental features of the words, no differences were detected between the reading groups.

One of the factors that influence the categorization of minimal pairs is the ISI length. Cutler (1986) has shown that when the ISI between items are small, spoken minimal pairs are perceived as homophones. Therefore Experiment 5, a same/different task where the ISI is varied between 50 ms and 500 ms, will examine whether the good readers might nonetheless use lexical information in the matching task whilst the poor readers would still limit themselves (or be limited to) the pre-lexical processing.

6 Experiment 5 - Stress processing in a same/different task

The aim of this experiment is to assess if good readers would utilise the suprasegmental as well as segmental features to decide if the words are the same or different?

In the previous experiment, the participants were asked to keep two sounds in memory and then distinguish which sound was presented first or second. The temporal order judgement task in Experiment 4 showed no discernable response latency differences between poor and good readers as the task may have been too difficult or the responses were too long a period (all RTs were all over a second). This experiment pits the abilities of poor and good readers against one another in a simpler same/different task where the items are spoken minimal same and contrastive pairs. The participant has to decide if identity pairs (trochaic-trochaic, iambic-iambic) and contrastive pairs (trochaic-iambic, iambic-trochaic) are the same or different, respectively. If the same and different minimal pairs are processed at the segmental level, the contrastive pairs will be erroneously classified as identity pairs. Therefore, the minimal pairs that can only be distinguished by their suprasegmental features, forces the good and poor readers to focus more on suprasegmental processing at the pre-lexical level rather than on the word's segmental features at the lexical level.

The ISI between items has been shown to affect the outcomes of the same/different tasks (Baum & Leonard, 1999; Luce, Goldinger, Auer, & Vitevitch, 2000). When the ISI is longer, it facilitates better comparisons between same and different. Cohen-Mimran and Sapir (2007) tested 12 years old children using a same/different tasks at varying ISIs. They found that some children with specific reading disabilities had difficulty discriminating pure tones at 50ms ISI but not 500ms ISI. In this experiment, same/difference minimal pairs will be presented to participants at 50ms and 500ms ISI.

For spoken word recognition pre-lexical and lexical processes are engaged in parallel (Dahan & Magnuson, 2006). Good readers, who have a preference for processing words segmentally and largely ignore the suprasegmental features when presented with English words (Cutler, 2008), will now have to process the word pre-lexical focusing on the words stress features. Dahan and Magnuson have suggested that whilst items are processed pre-lexically, they are also processed lexically at the same time; as such good readers may start processing the word segmentally, focusing on the words segmental features. This processing of words at the segmental level appears to be "automatic" for good readers (Experiment 3). However, if the pre-lexical processes predominate, then good readers will make a same/different decision based on the suprasegmental features. "English listeners can exploit suprasegmental stress cues in word recognition if they are given the opportunity" (Pisoni & Remez, 2004). If the items are processed at the pre-lexical level, it is *hypothesized that no frequency effects will be found*.

According to Studdert-Kennedy's (2002), the 50ms ISI will put the poor readers "under pressure" and *poor readers should make more errors than good readers at 50ms ISI.* Poor readers will process the items at the acoustic pre-lexical level and hence will not show any frequency effects. Poor readers have also processed some items with phonetic variation much faster than their normal reading peers as in experiment 3, thus poor readers may process the contrastive items equally as fast as they are processing the identity items. In identity priming (Scarborough & et al., 1977) the recognition of the second item benefits from the presentation of the first; therefore in this same/different experiment the minimal identity pairs should have shorter response latencies than the different contrastive items and identity pairs would also show fewer errors than the contrastive pairs. *It is therefore hypothesized, that good readers would show same-different effects between identity and contrastive pairs and poor readers may not show this same-different effect*.

6.1 Method

Participants

Twenty-four children from a local Catholic School in the outer Eastern suburbs of Melbourne took part in this experiment; some of these participants did participate in Experiment 4. Participants reported normal hearing and English to be their first language. There were 15 males (*M* = 11;5 *range 9;1-12;9*) and 9 females (*M* = 11;3 months, range 10;4-12;8). Their TOWRE scores are listed in Table 12 below.

Table 12

TOWRE Reading scores (standard deviation in parentheses) for children that are good and poor readers

	Good Reader	Poor Reader
Number of participants	16	8
Age(SD)	11;6 (1;0)	11;3 (0;9)
TOWRE Sight Word(SD)	103.6 (10.1)	86.4 (10.9)
TOWRE Phonemic decoding (SD)	106.8 (9.9)	81.1 (5.5)
TOWRE Percentile (SD)	61.9 (23.6)	12.25(7.6)

Material

The items were recorded in the same manner as in previous experiments. The material consisted of 16 spoken minimal contrastive pairs (refer to appendix D) consisting of 8 high-frequency items, CELEX spoken frequency M = 30.86 (SD = 8.25; range 19-40); 8 low-frequency items CELEX spoken frequency M = 2.31 (SD = .7; range 1.5-3.8). Each of the words was recorded at 44.1 KHz at 16 bit. The average file length for nouns was M = 76838 bytes (SD = 12800 bytes) and for verbs was M = 71418 bytes (SD = 6248 bytes). There was no difference in file sizes between verb and noun stimulus sets ($F(1,28) = 2.23$, $p = .15$). The difference between low-frequency files M = 73170 bytes (SD = 9010 bytes) and high-frequency files M = 75086 bytes (SD = 11635 bytes) was also non-significant ($F < 1$).

Procedure

Participants were tested in a quiet room at school where the children were always in full view of staff. Participants were tested in groups of two on laptops. Sound was relayed through earphones at a comfortable loudness. There were two sessions with the same stimulus pairs; one at 50 ms ISI and another 500 ms ISI. Each session took about 3 minutes, maximum. Half the readers started with the 50 ms ISI and the other half started with the 500 ms ISI condition. The test spanned a few days and in some instances, it took a few weeks to complete the two sessions for an individual. The maximum time lapse between two sessions was four weeks. Each list of items was scrambled, thus giving each participant a unique order of the trials. The following instructions were displayed before the start of each session.

> You will hear two sounds. Your task is to decide if the sounds are the SAME or DIFFERENT. If the sound is the same press the RIGHT button as fast as you can; if the sound is different press the LEFT button as fast as you can.
>
> A smiley face ☺ will tell you if you made the correct decision. A frowning face ☹will tell you if you made the wrong decision."

The participant was placed at a comfortable level in front of the laptop computer. The participant first completed a trial run, which consisted of 3 items for each condition that were not part of the experimental items. When the participant was not confident about the procedure, the trial run was repeated. The computer ran the DMDX software by Foster and Forster (2003). The trial would start with a '+' sign presented for 500 ms in the middle of the screen. Thereafter the participant would hear the stimulus item. The next trial started immediately after the response. When there was no response the next trial would start after 2000 ms. Timings were recorded immediately at the onset of the second word. The game-pad was programmed to start the session when the participant presses the right hand thumb button.

6.2 Results

The responses were analysed and response times less than 250 ms and greater than 1500 ms were excluded from analysis. Using these response times resulted in no respondent being excluded from further analysis. A 4-way ANOVA was conducted with Pair (identical, contrastive), ISI (500 ms, 50 ms) and Word Frequency (low-frequency, high-frequency) as within-participant factors and Reader (Good, Poor) the between-participant factors. A similar 4-way ANOVA was conducted on the errors scores. There were no 4-way interactions for response latencies ($F < 1$) and for errors results ($F < 1$).

Analysis of Frequency effects

Response latencies: If all processing was completed using pre-lexical processing or information from a pre-lexical level, then there should be no frequency effects. Contrary to expectations, there was a frequency effect. A 3-way ISI X Frequency X Reader interaction was significant ($F(1,22) = 4.5$, $p = .045$, $\eta^2 = .53$). Further analysis suggested that poor readers at 50 ISI had a significant frequency effect ($F(1,22) = 4.93$, $p = .037$, $\eta^2 = .56$).See the results of simple contrasts in Table 13 .

Table 13

Response latencies (RT) and percentage errors (Err) for Reader and ISI for identity and Frequency. The standard deviations are in parentheses.

Reader	ISI	Freq		
		HF	LF	Frequency Effect
Good				
500	RT	1034 (128)	1039(135)	+5
	Err	17 (15)	16 (16)	1
50	RT	1066 (112)	1039(110)	-27
	Err	20 (14)	20 (14)	0
Poor				
500	RT	1057(94)	1070(80)	+13
	Err	18 (13)	18 (16)	+6
50	RT	1006(78)	1054(73)	+48**
	Err	18 (10)	25 (15)	+7##

** $p < .05$, ## $p = .057$

Errors: High-frequency items showed fewer errors than the low-frequency items for poor readers at 50 ISI were almost significant with ($F(1,22) = 4.04$, $p = .057$, $\eta^2 = .49$). None of the other error percentages was significantly different between low-frequency and high-frequency.

Analysis of differences between Identity and Contrastive pairs

Table 14

Response latencies (RT) and percentage errors (Err) for Reader and ISI for identity and contrastive pairs. The standard deviations are in parentheses.

Reader	ISI	Pair		
		Identity	Contrastive	Response Effect
Good				
500	RT	1013(150)	1059(116)	46**
	Err	13 (15)	20 (17)	7**
50	RT	1036(116)	1068(103)	32**
	Err	15 (14)	24 (15)	9**
Poor				
500	RT	1054(106)	1074(64)	20
	Err	15 (15)	21 (16)	6
50	RT	1033(66)	1028(93)	-5
	Err	15 (8)	27 (16)	12**

** $p < .05$

Response Latencies: The interaction between Reader, ISI and Pairs was not significant ($F < 1$). However, post-hoc analysis of simple effects, suggested that good readers showed a difference between identity and contrastive pairs, whereas poor readers did not show any identity and contrastive differences in response latencies as listed in Table 14 above. Good readers showed a significant difference between identity and contrastive pairs at both levels of ISI: at 500ms ISI ($F(1,22) = 7.98$, $p = .01$, $\eta^2 = .77$) and at 50ms ISI ($F(1,22) = 4.34$, $p = .049$, $\eta^2 = .51$). If poor readers processed the stimuli as acoustic items only, and they listened for similar patterns or different patterns only, then there should not be any difference between identity and contrastive pairs. Poor readers, indeed, did not show any difference between identity and contrastive pairs at 500ms ISI ($F < 1$) and at 50ms ISI ($F < 1$). There was also an overall main effect with identity pairs being 23ms faster than contrastive pairs ($F(1,22) = 5.29$, $p = .031$, $\eta^2 = .59$), with much of this attributed to the good reader.

Errors: When the errors were analysed between identity and contrastive (refer to Table 14) *the* errors at 500 ms ISI (F (1,22) = 4.82 $p = .04$, $\eta^2 = .56$) and at 50ms ISI ($F(1,22) = 8.82$, $p = .007$, $\eta^2 = .81$ for Good readers were significant. The *poor reader* errors for contrastive and identity pairs were not significant at 500 ms ISI (F (1,22) = 1.6, $p = .22$, $\eta^2 = .23$) but was significant at the 50 ms ISI (F (1,22) = 7.23, $p = .013$, $\eta^2 = .73$). The contrastive pairs had 8.5% more errors than the identity pairs ($F(1,22) = 12.7$, $p = .002$, $\eta^2 = .93$)

6.3 Discussion

The results partially confirm the hypotheses. Good readers did show RT differences between identity and contrastive pairs where poor readers did not show any RT differences. Like Experiment 3 and 4, when items were processed explicitly at the suprasegmental level, no frequency effects were found, except poor readers showed a frequency effects at the 50ms ISI. It was expected that identity pairs would have better response latencies than the contrastive pairs for good readers at 500 ms and 50 ms ISI, however, poor readers did not show any latency difference between identity and contrastive pairs. These findings are discussed below. The differences between identity and contrastive pairs are discussed first.

Good readers could have processed the identity pairs at the segmental level. However, if they did, one would expect to see frequency effects and these were not evident at all for good readers. There is another explanation, the difference could be due to “acoustic” and segmental processes operating in parallel (Dahan & Magnuson, 2006). For the poor readers the acoustic processes are sufficient, whereas the good readers processed some of the items segmentally whilst the acoustic processes still prevailed. If the segmental processes pre-dominated then there should have been frequency effects. What is significant in these results is the difference between identity and contrastive pairs for good readers. The error profile of the good readers matches that of their latency response profile, with contrastive pairs generating more errors. The error differences between identity and contrastive pairs were also significant, with identity pairs eliciting fewer errors than contrastive pairs for good readers. For the identity pairs the words overlap segmentally and prosodically which facilitates identity priming (McQueen & Sereno, 2005).

For the contrastive pairs the words were a combination of verbs and nouns with contrastive stress. For the good readers the trochaic items would have started lexical access due to the strong first syllable (Mattys & Samuel, 2000) and then additional processes delayed the response to contrastive items; thus creating a difference between the identity and contrastive pairs. And, although Cutler (2008) claimed that good readers do not generally utilise suprasegmentals to process English words, this experiment suggest that good readers can explicitly process suprasegmentals.

Serniclaes and colleagues have shown that poor readers were better at processing within-category contrasts in allophones. (Bogliotti, Serniclaes, Messaoud-Galusi, & Sprenger-Charolles, 2008; Serniclaes, Van Heghe, Mousty, Carre et al., 2004) The reason for the sensitivity is because most infants have the ability to assess all contrasts in their language for about a year (Werker & Tees, 1987), then they "loose" this ability; except dyslexic children seem to retain some of this ability. A principal assumption made in this thesis is that this sensitivity to language contrasts persists in poor readers. Therefore, if poor readers used acoustic/phonetic processes only, then the number of errors should have been substantially reduced. Furthermore, if poor readers are more sensitive to stress variation then again it was expected that poor readers would perform better at contrastive processing relative to processing of identity pairs. One could argue that poor readers did equally poorly at responding to identity and contrastive pairs, as they too had "difficulty in discriminating and identifying phonetically similar (although phonological contrastive) syllables under pressure" (Studdert-Kennedy, 2002, p. 11). This assertion is supported by the fact that the performance of poor readers for 50ms ISI and 500ms ISI were not significantly different, because they processed identity and contrastive pairs equally well as identity items. However, poor readers did not show an error difference for the 500 ms ISI; but they did make a number of errors at the 50ms ISI for identity and contrastive pairs. Again this is to be expected, when processing contrastive stress under pressure (Studdert-Kennedy, 2002) at the shorter 50ms ISI.

It was expected that none of the processes would show frequency effects and this is borne out by almost all the results, except for poor readers at the 50ms ISI. Their high-frequency items had a much shorter response latency than the low-frequency items (see **Table 13**). This faster processing of contrastive pairs may explain the frequency effect where the different high frequency prime in conjunction with the strategic processes of anticipating a word with opposite stress pattern may have produced this trade off where poor readers showed a frequency effect. This anomaly of a frequency effect and faster response latency at the contrastive pair condition may require further research.

In summary, this study shows that poor readers processed the items phonetically – i.e., at the signal level only. Unfortunately, I cannot make a strong claim of this phonetic pre-lexical level processing because of the anomaly where the 50ms ISI produced a frequency effect. While Experiment 3 indicated that poor readers were efficient at processing single items (at the phonetic level), this experiment indicated that when poor readers have to process identity and contrastive pairs they had difficulty whilst under pressure. Good readers on the other hand showed the expected results; differences in RTs and errors between identity and contrastive pairs.

The last experiment is a priming auditory lexical decision task where the prime and target have contrasting stress. In this task, lexical decisions can be made by attending to segmental properties of the word only. However, since poor readers focus more on pitch (see Experiment 3) it is predicted that poor readers will be constrained by unnecessarily processing suprasegmentals.

7 Experiment 6 - Stress priming in a lexical decision task

The aim of this final experiment is to assess if poor readers would focus more on suprasegmental features and distinguish minimal pairs as non-homophonic words in a lexical decision task, while good readers process the same minimal pairs segmentally as homophones.

In Experiment 5, readers were given explicit instruction to distinguish between same and different minimal pairs. It has been noted in the introduction that lexical stress constrains lexical access. What is not clear is whether the stress features of words are stored in the lexicon and whether post-lexical matching uses this stored information once the word has been recognized. If the stress properties of a word are stored, presumably then one could use words that match the stress patterns to get a priming response.

This notion was tested by Schiller et. al. (2004) and Slowiaczek et. al. (2006). Schiller et. al. (2004) used a picture naming task with cross modal priming in Dutch to assess the responses to disyllabic words and whether lexical stress could be primed; that is, whether the lexical stress of the word describing the picture influences the recognition of the target word. Participants were presented with a picture of a (Dutch word FoREL – “trout”) with varying stimulus onset asynchrony (SOA), which is the time difference from the onset of the picture to the onset of the second word. After the picture was shown, the participants were presented with a trochaic (Dutch word KARper – “carp”) or iambic (Dutch word maKREEL – “mackerel”) related target, or a trochaic (Dutch word KEtel – “Kettle”) or iambic

(Dutch word vamPIER – vampire) unrelated target. Schiller and associates did not find any priming effects between similar stress pairs and contrastive pairs and concluded that stress is not stored with the word in the lexicon. But, they did process trochaic target words faster than iambic target words. Schiller et. al. argued that the trochaic stress advantage is utilized in an encoding strategy to access the words.

Slowiaczek et. al. (2006), also tested this notion of lexical stress representation using university students in a auditory naming task under three conditions: 1) *same* lexical stress (e.g.., RATing – LIFEtime), 2) *different* lexical stress (e.g.., ciGAR – LIFEtime), and 3) an *identical* pair (e.g.., LIFEtime – LIFEtime). Each participant was presented with an auditory prime and the auditory target was presented 100 ms after the offset of the prime. Their results showed that the identity pairs were named faster than same pairs, and different pairs, with no difference in response times between the same and different pairs. Slowiaczek et. al. interpreted their results to indicate that lexical stress patterns are not stored in lexical memory. Schiller et al (2004) and Slowiaczek et. al. (2006) suggested that the stress properties of the word are used to form a trace pre-lexically to access the words. This trace could then be used to anticipate a target word when the prime and target have alternating stress patterns, and if the listener is aware of the primes stress pattern.

This final experiment will investigate whether poor readers rely more on suprasegmental features to form this trace even if it might not be required. Recall that in Experiment 3, participants were told that they could use the stress properties of the disyllabic words or the semantic knowledge of a word to categorize verbs and nouns. In that experiment, poor readers appeared to use the word's stress properties whereas good readers used the semantic knowledge of the word, which they could have ignored to make a categorization of verb or noun. In this last experiment, a primed lexical decision task, the target and prime will have either iambic or trochaic stress. To test the sensitivity to suprasegmental features, the stress properties of the prime and target words/non-words will be alternated; that is, lexical stress is alternated between 1st and 2nd syllables of the prime and target.

This experiment uses an auditory priming lexical decision task with two conditions, 1) *segmental similar (SS)* condition (SECond → seCOND and seCOND → SECond) and 2) *base* condition (PUBlic → seCOND and beCOME → SECond). One of the reasons for this alternating lexical stress is the expectation that poor readers will detect the alternating nature of the lexical stress location in the stimulus items and strategically anticipate the stress properties of the target, and show response latency differences between iambic and trochaic items. Good readers, may ignore this extra information because it's not required, and will process the target items segmentally as homophones.

In the *segmental similar* condition, the expectation is good readers will ignore segmental features and process the prime and target as homophones at the segmental level. When we consider the two routes used in acoustic-phonetic word recognition, in the *segmental similar* condition it's expected that the phonetic (segmental) processing will predominate for good readers. For poor readers who may process the items phonetically and segmentally, the segmental nature of the prime and target may predominate and mask the acoustic processing. It's *therefore* *hypothesized that good and poor readers will process words similarly in the segmental similar condition*.

In the base condition, the prime is segmentally different to the target and the explicit processing of the suprasegmental information may influence the target word recognition. Recall, Murray and Forster (2004) contended that other factors such as “concreteness, length, regularity and consistency, homophony, number of meanings, neighbourhood density, and so forth..”(p.721) may influence word recognition but show effects at low frequency ranges only. Therefore, poor readers who are aware of the alternating stress pattern may utilize this stress pattern for low-frequency items. *It’s therefore hypothesized that in the base condition, if poor readers anticipate the target stress pattern strategically, then one could expect that trochaic items (which have a processing advantage) will be processed faster than iambic items for low-frequency items for poor readers only.*

Like the study by Slowiaczek et. al. (2006) it’s expected that the base items will have longer response latencies than the segmentally similar items. It’s therefore hypothesized *that there will be a priming effect between the segmentally similar condition and base condition*. Furthermore, like the results of Slowiaczek’s and Schiller et. al. (2004) *its hypothesized that trochaic items will have shorter response latencies than iambic items*.

7.1 Method

Participants

Twenty-eight children from two Catholic Schools in the outer Eastern suburbs of Melbourne took part in this experiment. Participants reported normal hearing and English to be their first language. Children were divided into good and poor reading groups; refer to Table 15 for TOWRE reading scores.

Table 15

Age and mean standardized scores for good readers and poor readers as identified by the TOWRE test

	Good Reader	Poor Reader
Number of participants	19	9
Age(SD)	11;5 (1;0)	11;1 (0;9)
TOWRE Sight Word(SD)	103.0 (10.2)	85.9 (10.3)
TOWRE Phonemic decoding (SD)	107.6 (9.3)	82.3 (6.3)
TOWRE (SD)	62.8 (22.2)	12.4 (7.2)

Material

The target items consisted of 12 high-frequency noun-verb pairs, and 12 low-frequency noun-verb pairs. High frequency items had an average spoken CELEX value of 128.72 (*SD* = 89.31) and low-frequency items had an average spoken CELEX value of 4.29 (*SD* = 5.01). The items were recorded at 44.1khz at 16 bits. The file lengths for high-frequency nouns were *M* = 77577 bytes (*SD* = 10918 bytes), high-frequency verbs M = 73007 bytes (SD = 9358); low-frequency nouns were *M* = 69522 bytes (*SD* = 13038 bytes), low-frequency verbs *M* = 66826 bytes (SD = 8684); There was no difference in file sizes between verb and noun stimulus sets ($F(3,44) = 2.29$, $p = .091$)

A set of non-words were created consisting of two syllables with CCVCVC and CVCVC skeletal level structure (refer to appendix D). These items were recorded and stress placement was alternated between the syllables to create trochaic and iambic non-words. For example, the non-word “blotay” was pronounced BLOTay and bloTAY.

Furthermore, a set of non-related disyllabic words were chosen that 1) did not match on the first syllable, 2) had the same (or almost) the same frequency as the target spoken noun-verb monographs. The items were arranged in contrastive sets; that is, in trochaic-iambic and iambic-trochaic pairs. See Appendix D for a list of all the items.A sample of the prime and target pairs are listed in the Table 16.

Table 16

Example combinations of trochaic – iambic stimulus pairs with associated non-words (NW) targets (and HF and LF frequency range in Appendix E)

	Freq	Iambic Target	Frequency range		Trochaic Target
Contrast	HF	SECond → seCOND or NW	46-334		seCOND → SECond or NW
	LF	FERment → ferMENT or NW	0.1-1.54		ferMENT → FERment or NW
			Frequency Range		
			iambic	Trochaic	
Base	HF	PUBlic → seCOND or NW	50-345	64-520	beCOME → SECond or NW
	LF	BUILDer → ferMENT or NW	.77-1.54	0.1-1.54	ComMUTE → FERment or NW

LF = low-frequency; HF = high-frequency ; NW = non-words

The combinations created a total set of 48 Trochaic-Iambic, 48 Iambic-Trochaic pairs and 96 word-non-words pairs. The words were recorded in carrier sentences using Praat (Boersma & Weenink, 1992-2007). Each of the words and non-words were analysed to ensure that pitch contour was rising for verbs and descending for nouns.

Procedure

Participants were tested in pairs in a quiet room at school where the children were always in full view of staff. Each participant was tested on a laptop computer. Sound was relayed through earphones at a comfortable loudness. Given the number of items, there were three rest periods every 2-3 minutes. The task took about 8-10 minutes, maximum. The items were divided into 12 blocks ensuring that each item appeared no more than once in a block. Each block of items was scrambled thus giving each participant a unique order of the trials. The following instructions were displayed before the start of the trial and experimental items.

> You will hear two sounds. Your task is to decide if the second sound is a WORD. If the sound is a word press the RIGHT button as fast as you can; if the sound is not a word press the LEFT button as fast as you can. A smiley face ☺ will tell you if you made the correct decision. A frowning face ☹ will tell you if you made the wrong decision."

The participant first completed a trial run. When the participant was not confident about the procedure, the trial run was repeated. The trial run consisted of three different items from each condition. The computer ran the DMDX software by Foster and Forster (2003). The trial would start with a '+' sign presented for 500 ms in the middle of the screen. Thereafter the participant would hear the stimulus item. The next trial started immediately after the response or after a period of 2000 ms timeout period. Timings were recorded at the onset of the second word. The Logitech game pad was programmed to start the session when the participant pressed the right hand thumb button. The left and right hand buttons were programmed to record the “NO it is not a word” and “YES it is a word” answers respectively.

7.2 Results

Items with response times less than 250 ms and greater than 1500 ms were excluded from analysis, and trimming of items were achieved at two standard deviations. Using this criterion, no respondents were excluded from further analysis. Separate ANOVAs were conducted on the data listed in Tables 19 and 20 below.

Analysis of priming effects

Separate 4-way ANOVAs were conducted on the response latencies and errors, with Frequency (low v high) by Pair (SS v Base) by Stress Type (iambic v trochaic) as within subject factors and Readers (poor v good) as between subject factors. There were no significant 4-way, 3-way, or 2-way interactions.

Response Latencies and errors: Referring to Table 17, there was a consistent positive priming effect across both Reader groups, with the segmentally similar items responded to 98ms faster than base items (F(1,26) = 8.46, p = .007, η^2 = .25). There was also a positive priming effect for errors, where the base pairs had 13% more errors than the segmentally similar pairs (F(1,26) = 36.48, p < .001, η^2 = .58).

Table 17

Response latencies and percentage errors (in parenthesis) for Prime Type by Reader

Reader	Pairs		
	SS	Base	Prime Effect
Good	969(13)	1064(24)	95**(11**)
Poor	954(16)	1055(31)	101**(15**)

** $p < .05$, SS = Segmentally similar

Response Latencies and errors: Referring to Table 18, there was a consistent main effect for Stress Type across Reader groups, where trochaic items were recognised 21ms faster than the base items ($F(1,26) = 8.46$, $p < .007$, $\eta^2 = .25$). There was a comparable main effect for the errors, where iambic items had 7% more errors than trochaic items ($F(1,26) = 15.74$, $p < .001$, $\eta^2 = .38$).

Table 18

Response latencies and error (in parenthesis) stress type differences between Good and Poor Readers

Reader	Stress Type		
	Iambic	Trochaic	Stress Effect
Good	1025(23)	1008(15)	17(8**)
Poor	1018(27)	992(21)	26**(6**)

** $p < .05$

Separate analysis of Segmentally similar and Base Condition

To assess if good and poor readers used different strategies to process items in the segmentally similar condition and the Base condition, separate analyses were conducted on the details in Table 19 and Table 20 below.

Table 19

Mean RTs and standard deviation in brackets for between Good and Poor Readers

		Base				SS			
		HF		LF		HF		LF	
Reader		Iambic	Trochaic	Iambic	Trochaic	Iambic	Trochaic	Iambic	Trochaic
Good	RT	1067	1048	1084	1057	977	966	971	962
		(100)	(113)	(104)	(98)	(112)	(89)	(88)	(117)
Poor	RT	1040	1054	1100	1027	954	929	976	959
		(92)	(128)	(46)	(127)	(103)	(92)	(91)	(122)

Segmentally similar item response latencies: A 3-way ANOVA with Stress Type (Iambic v Trochaic) x Word Frequency (High v Low) as within-participant factors and Reader (Good v Poor) as a between-participant factor was conducted for the segmentally similar (same) items. There were no significant interactions and main effects; nor where there any differences between readers (see *Figure 1Figure 14*).

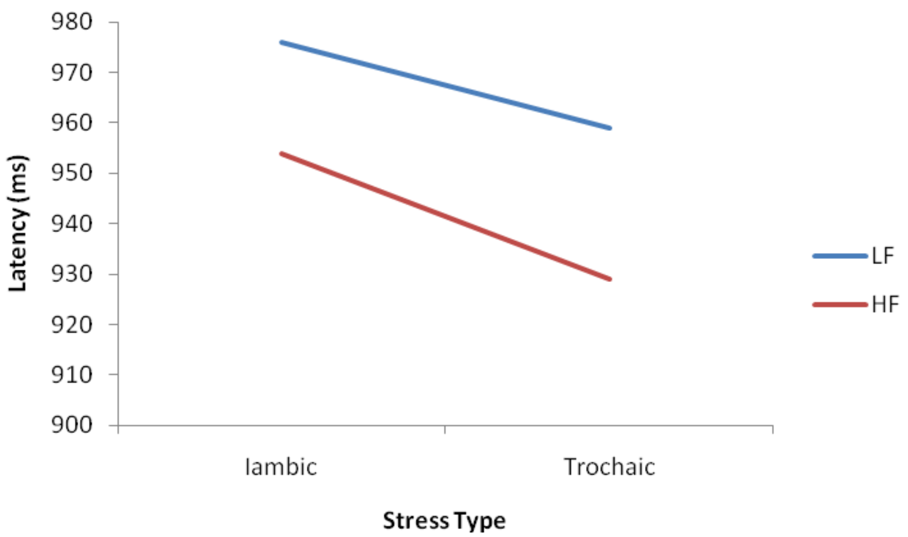

Figure 14. Mean response latencies for poor readers in the *segmental similar* condition between stress type for low and high-frequency

Base item response latencies: A similar 3-way ANOVA was conducted for the base items in Table 19. The results showed a significant 3-way Frequency by Stress Type by Readers interaction ($F(1,26) = 5.0$, $p = .034$, $\eta^2 = .16$). Further analysis (refer to *Figure 15*) of the low-frequency items showed a 73 ms different between trochaic and iambic items for poor readers only ($F(1,26) = 11.5$, $p = .002$, $\eta^2 = .31$). Analysis of frequency effects showed that low-frequency items were 60ms slower than high-frequency items ($F(1,26) = 7.74$, $p = .01$, $\eta^2 = .23$). Good readers attended less to the suprasegmental features and appeared to process the items segmentally; they did not show any significant frequency effects nor lexical stress effects. However, their results do trend in the right direction (refer to *Figure 16*).

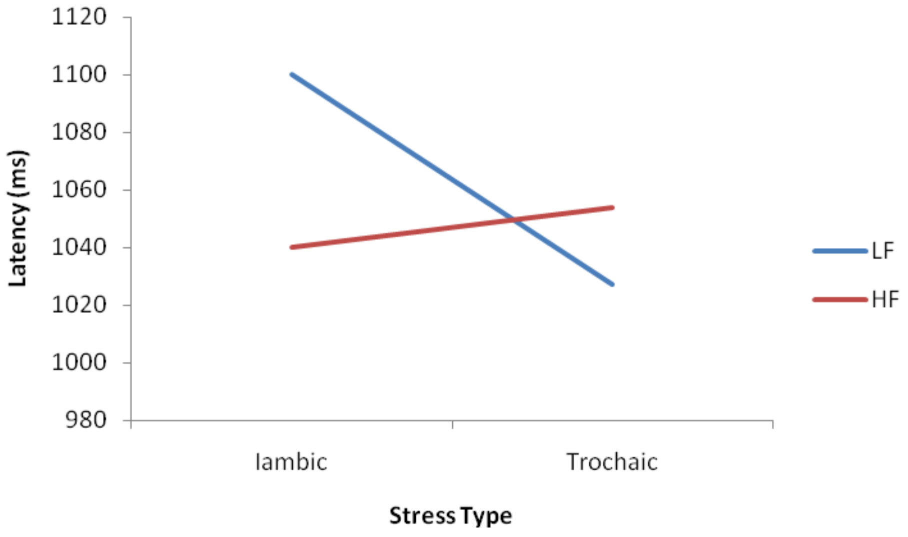

Figure 15. Mean response latencies for poor readers between low and high-frequency for each level of stress type.

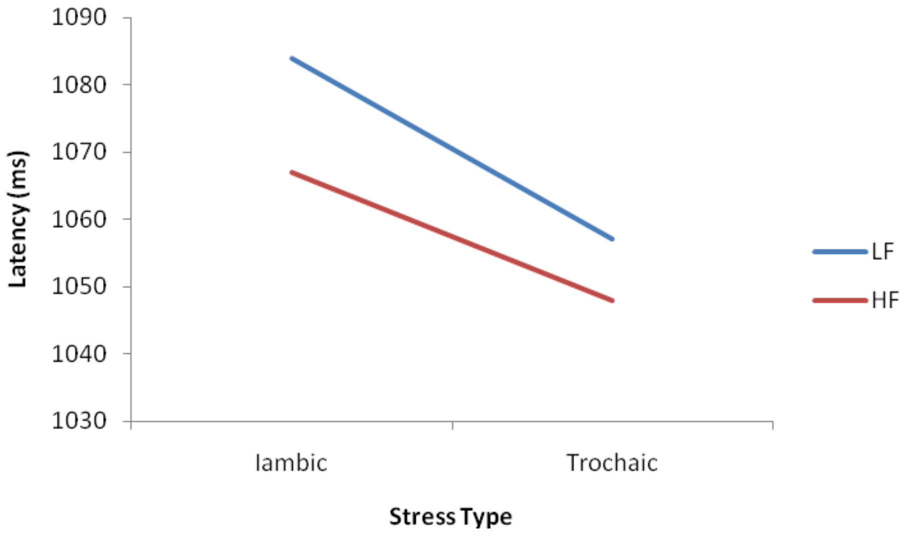

Figure 16. Mean response latencies for Good readers between low and high-frequency for each level of stress type

There was also a 2-way interaction (refer to *Figure 17*) between Frequency and Stress Type ($F(1,26) = 7.1$, $p = .034$, $\eta^2 = .21$). Analysis of the interaction suggested that high-frequency items were 38ms faster than low-frequency items for iambic items only ($F(1,26) = 8.6$, $p = .007$, $\eta^2 = .25$). Trochaic items were 50ms faster than iambic items (F(1,26) = 14.6, p < .001, η^2 =.36) for low-frequency items, resulting in a main effect for Stress Type with trochaic items being recognised 26 ms faster than iambic (F(1,26) = 6.45, p = .017, η^2 = .20).

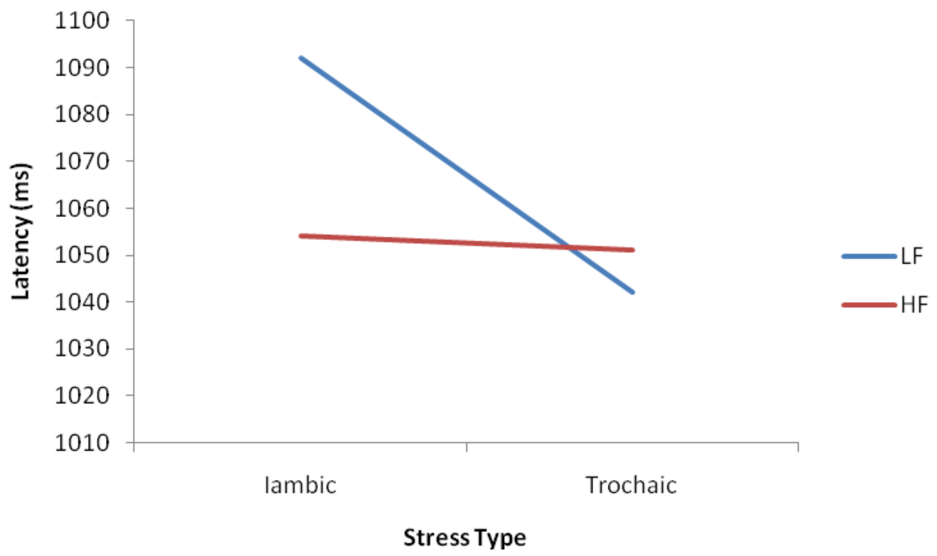

Figure 17. Mean response latencies for Stress Type between low and high-frequency for each level of stress type

Analysis of error percentages

Table 20

Mean Errors and standard deviation in brackets for between Good and Poor Readers

		Base				SS			
		HF		LF		HF		LF	
Reader		Iambic	Trochaic	Iambic	Trochaic	Iambic	Trochaic	Iambic	Trochaic
Good	Error	22.6	17.2	32.7	25.2	18.4	5.6	16.5	11.7
		(15.7)	(19.2)	(16.9)	(14.5)	(16.5)	(10.5)	(13.5)	(7.7)
Poor	Error	30.5	22.6	38.8	32.7	17.3	5.6	20.0	22.6
		(16.5)	(11.7)	(19.2)	(18.7)	(15.9)	(8.4)	(15.4)	(15.5)

Segmentally similar (SS) item Errors: A 3-way ANOVA Stress Type (iambic v trochaic) x Word Frequency (High v Low) as within-participant factors and Reader (Good v Poor) as a between-participant factor was conducted on the error data in Table 20 for the segmentally similar (same) items. There were no significant 3-way interactions. There was a Stress Type x Frequency 2-way interaction ($F(1,26) = 16.4$, $p < .001$, $\eta^2 = .39$). Further analysis (refer to *Figure 18*) showed that iambic items had 12% more errors than trochaic items for high-frequency items only ($F(1,26) = 28.7$, $p < .001$, $\eta^2 = .53$). There was a frequency effect ($F(1,26) = 18.4$, $p < .001$, $\eta^2 = .41$) with low-frequency items having 11.5% more errors than high-frequency items for trochaic items only.

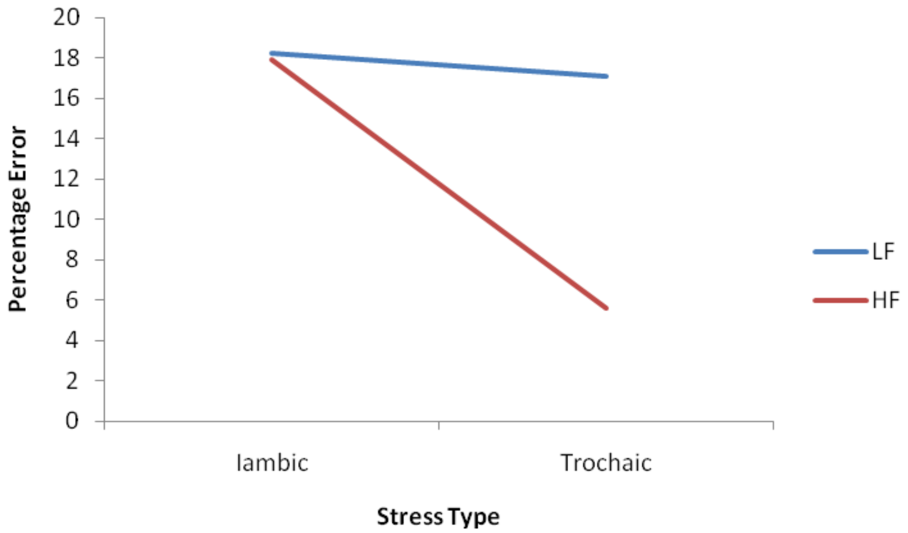

Figure 18. Error Percentages between iambic and trochaic items for each level of frequency.

Base item Errors: A 3-way ANOVA Stress Type (iambic v trochaic) x Word Frequency (High v Low) as within-participant factors and Reader (Good v Poor) as a between-participant factor was conducted on the error data in Table 20 for the base items.

There were no significant 3-way and 2-way interactions. There was a main effect for Stress Type ($F(1,26) = 7.4$, $p = .012$, $ŋ^2 = .22$) with iambic items having 7% more errors than trochaic items. There was also a main effect for frequency ($F(1,26) = 10.1$, $p = .004$, $ŋ^2 = .28$) with low-frequency items having 9% more errors than high-frequency items.

7.3 Discussion

The hypotheses were supported. There was a priming effect between the segmentally similar and the base condition. Trochaic items had faster response latencies than iambic items. Good and poor readers processed prime-target pairs (reCORD/RECord) segmentally in the *segmental similar* condition; there were no significant interactions and main effects. It appears that poor readers were sensitive to the alternating stress pattern of the prime and target and processed prime-target pairs (PUBlic/reCORD) using suprasegmental features (refer to *Figure 15*). These findings are discussed below.

In this priming study, the segmentally similar items had shorter response latencies because they were processed as identity pairs; the prime and target items were processed as segmentally identical items. The response latencies of the base prime-target pair were slower because the items were segmentally different and the base item did not prime the target item. And like the results of Schiller et. al. (2004) and Slowiaczek et. al. (2006) the trochaic items were processed faster than the iambic items.

In the *segmental similar* condition, the prime and target are segmentally the same. Spoken word recognition involves acoustic/phonetic processes that operate in parallel. The acoustic processes focus on the suprasegmental features, and the phonetic processes focus on the segmental features of the spoken words. The phonetic process pre-dominated in this *segmental similar condition* and the target words were recognized segmentally, as there were no significant interactions and main effects. This is not to say that poor readers did not make use of the acoustic/suprasegmental processes as shown by the stress type in the graph in *Figure 14*. And one of the reasons why poor readers could have changed their strategy is repetition priming. When the prime (reCORD) was heard the first time, the trace was created that related to both forms of the word (e.g., reCORD and RECord). When the second word with alternate stress pattern was heard, after 50ms ISI, the segmental representation of the target word was already activated and therefore recognized much quicker. However, this same activation processes could also have been the cause of the errors found in the *segmental similar* condition. There were two general findings, iambic items had more errors than trochaic items for high-frequency items only; and low-frequency items had more errors than the high-frequency items for trochaic words only. The results in this experiment concur with those from Experiment 1 and 2 where high-frequency trochaic items had fewer errors than the low-frequency trochaic items, and generally, the trochaic items were recognized faster than the iambic items. The lexical stress differences suggest that the items were processed using the word's suprasegmental features, as trochaic items create a trace much earlier than the iambic items. Consider the RECord-reCORD prime-target pair, the trochaic prime initiates the trace and activates the trochaic word RECord in the lexicon, then the iambic target word reCORD is heard. In the high-frequency condition the trochaic prime word could be fully activated when the iambic target that requires retroactive processing is presented, causing interference in the *response decision phase* of lexical decision task, creating errors as a result.

In the *base* condition, the prime and the target are segmentally different. In *Figure 15*, poor readers got better response latencies for trochaic items compared to iambic items for low-frequency items only. A possible explanation for this result is poor readers processed the words as typical nouns and verbs, which was not required. They could have processed the target items as homophones like the good readers did. Why would poor readers attend to the lexical stress of these items when it appears that they did not attend much to the suprasegmental features during the *segmental similar* condition? The alternating pattern may have had an influence. If the prime was iambic and the poor reader was expecting a trochaic item as the target, there could be an advantage to encode the trace for the trochaic item.

If the item is classified as typical in its class, like Experiment 3, where words with a falling pitch are typical nouns and words with a rising pitch are verbs, then the typicality effect would take precedence (see explanation in Experiment 1). Moreover, since nouns are more frequent, one could expect typical nouns to have better response than verbs for low-frequency items. This typicality effect concurs with the more recent work by Arciuli and Cupples (2003, 2004). Why is the converse not true as well? Iambic verbs are typical. In chapters 1 and 2 we've noted that words with a strong first syllable are processed faster than words with a strong second syllable. Some have even suggested that words with a strong second syllable need retroactive processing Cutler (1989) and hence spoken word recognition will take longer. Trochaic words or more specifically, words with falling pitch are more common that words with rising pitch. Therefore in the low-frequency situation, the typical noun with its falling pitch is recognized faster in the low-frequency condition.

In the previous experiments where the participants made decisions based on pre-lexical information only, results often did not show any frequency effects. In this experiment the items were processed at the lexical level and frequency effects were expected, in particular, high-frequency items were responded to faster than low-frequency items. However the frequency effect is masked somewhat when strategic processes also operate in word identification. When items are repeated the participants begin to anticipate certain result, which undermines the frequency effects. In this experiment the composition of just minimal pairs as target words where the prime and target have alternate stress patterns were constructed to facilitate “extrinsic” factors; that is, the composition of the list affects some of the results (Connine et al., 1993). The target items appear at least 4 times as a trochaic items and 4 times as an iambic item. However, if the target item was processed at the segmental level only, then the target items appears 8 times. Given the high probability that the target word could be a word belonging to a minimal pair, participants could anticipate the target word. This was indeed the case for the good readers.

In summary, poor readers are more sensitive to suprasegmental stimuli than good readers are, they processed minimal pairs by utilising their trochaic or iambic features. Good readers ignored the suprasegmental features and processed the items at the segmental level. Poor readers appear to continue to process suprasegmental features, even when they were not required. Lastly, what the results emphasise is the difference between good and poor readers when processing contrastive stress, and the sensitivity of the poor readers to these lexical stress variations.

8 Discussion

8.1 Rationale

Before summarising the findings of the six experiments, let us first review the rationale for this study. The first question was, in spoken word recognition are poor readers more sensitive to lexical stress than good readers are are? Infants, according to Aslin, Saffran et al. (1998), have the ability to discern all phonetic contrasts. However, after a year this ability is reduced as the infant's speech sound discrimination begins to match that of the adult community. Moreover, although the research suggests that readers in general lose the ability to discern phonetic contrasts, as they get older, it appears that poor readers might persist in using this "ability". The premise of this thesis is that poor readers are more sensitive to phonetic contrasts, and so is more sensitive to lexical stress (prosody) than their good reading peers.

One can surmise that much of the early word recognition processing occurs at the pre-lexical level whilst the infant is building a lexicon of words. The study by Serniclaes et. al. (2001) further supports this notion: dyslexic children are more sensitive to variations on a continuum and are therefore able to better discern phonetic contrasts within phonemic boundaries (eg. Allophones). Could it be that poor readers retained some of this sensitivity listed by Aslin, Saffran et al. (1998) and Serniclaes et. al. (2001), and that this "sensitivity" at the pre-lexical level constrains the poor reader rather than assist the reader in acquiring reading skills? This thesis finds that poor readers are more sensitive to suprasegmental features of bisyllabic words and in some situations are quite proficient in processing suprasegmental features to their advantage. . This is supported in Experiment 3, however, this sensitivity could also detract from performance as poor readers automatically attend to suprasegmental features when it was not needed (e.g., Experiment 6).

The second question was what is the difference between adults, good readers and poor readers when processing lexical stress in spoken word recognition? This question is answered in terms of six experiments that show listeners are sensitive to lexical stress, and there are differences between good and poor readers in the processing of lexical stress. Generally, poor readers are more sensitive and attend more to suprasegmental features explicitly, whilst good readers and adults largely ignore the suprasegmental features and process most spoken words segmentally (Cutler, 2008).

For Experiments 1 and 2, the lexical decision task items were structured to utilize extrinsic factors (Connine et al., 1993). That is, illegal non-words were used so that the listeners would utilise their phonological process mechanisms, in particular using pre-lexical processes. The reading ability of adults was not assessed in Experiment 1 hence the results showed that English adult listeners, irrespective of reading ability, performed better at recognising typical stress patterns, particularly trochaic nouns, compared to atypical stress patterns (Arciuli & Cupples, 2003). Stressed syllables assist in initiating lexical access (Cooper et al., 2002; Cutler & Norris, 1988; Wingfield et al., 1997), and therefore words with trochaic stress have an advantage over words with iambic stress as lexical access is initiated earlier at word onset (Mattys & Samuel, 2000; Mattys, 2000). However, there is an anomaly, sometimes typical iambic words are recognised faster than trochaic words.

8.2 Typicality

The primary means by which adults recognise spoken words is by using phonotactics (Vitevitch, 1998; Vitevitch & Luce, 1999; Vitevitch, Luce, Charles Luce, & Kemmerer, 1997; Vitevitch, Luce, Pisoni, & Auer, 1998), however, Experiment 1 showed that adult participants still attend to suprasegmental features. There was an interaction between frequency and typicality with typical disyllabic items having an advantage over atypical disyllabic items but only for low frequency items. These results auger well with the research on typicality (Arciuli & Cupples, 2003, 2004, 2006; Kelly, 2004). This is not unusual as early reading research showed that regular grapheme-phoneme correspondences were announced faster than irregularly spelled words but only for low frequency items (Seidenberg, 1985; Seidenberg et al., 1984). Furthermore, Murray and Forster (2004) asserted that other factors, including *regularity (*i.e., typicality) affect word recognition for low frequency words. Seidenberg et. al. (1984) explained this typicality effect using a race model. The processes utilising typicality and frequency race one another to recognise the word, if the process that utilises frequency takes too long, the process utilising typicality prevails.

An issue with stress-based models of word recognition is that they do not adequately explain how iambic words like ciGAR and hoTEL are processed. Generally, these words do not seem to cause difficulty to listeners. It has been suggested that iambic items are processed using the stressed syllable to form a trace to the lexicon. Once this trace is established, the first syllable is then processed retrospectively as part of an “ancillary strategy” (Cutler, 1989). Therefore, disyllabic items with lexical stress on the first syllable will be recognised faster than items with lexical stress on the second syllable. The findings in this research support this claim and good readers and adults have demonstrated that trochaic items are indeed better perceived than iambic items when processing items at the lexical level. Most disyllabic nouns are trochaic (Kelly, 2004), and hence the nouns used in Experiment 1 were recognised faster than the verbs, which are typically iambic. The finding that iambic items in Experiment 1 took longer to recognise, again supports the claim by Mattys and Samuel (2000) that the stress syllable in iambic items is perceived after a temporal delay caused by processing the unstressed first syllable.

8.3 Poor Readers processing of disyllabic words

Reviewing Experiment 2, the comparison between children and adults, we found the children had longer RTs than adults when recognising disyllabic words. The results are supported well by the studies by Lahey and colleagues (Edwards & Lahey, 1993; Lahey, Edwards, & Munson, 2001) who argued that longer RTs do not indicate deficiency in processing or representation, rather these delays are mainly dexterity differences between children and adults. Nevertheless, what about the good and poor readers, were poor readers slower than their peers? Edwards and Lahey (1996) claimed that there should be no error differences between good and poor readers, but poor reader’s responses should be significantly slower than the good reader’s responses. Crosbie et. al., (2004) claimed just the opposite to Edwards and Lahey, asserting that poor readers may have fuzzy representations and thus there would be no difference in response latency between good and poor readers, but poor readers would make more errors than good readers. Poor readers made more errors than adults did in Experiment 2, but when good and poor readers were compared, they did not show any differences in errors or response latencies. Overall, this result did not auger well with the results of either Crosbie et. al. (2004) or Edwards and Lahey (1996). This difference could be due to the small number of poor readers in Experiment 2. Further analysis of Experiment 2 data, suggested that poor readers may have used a different strategy to process disyllabic words. This is based on the finding that iambic and trochaic words showed no frequency effects, suggesting that their acoustic-phonetic processes differed to the rest of the participants. This lack of frequency effect was confirmed in Experiment 3, when poor readers used an acoustic strategy to categorise words.

8.4 Reader's differences

Poor readers

The results from Experiment 2 indicate that poor readers may have processed suprasegmental features differently to good readers and adults. However, to confirm this notion of sensitivity to suprasegmentals, the categorization (Experiment 3) and lexical decision (Experiment 6) tasks are discussed together as they complement one another.

In Experiment 3, the stimulus items were typical nouns and verbs, thus a noun/verb categorization could be achieved by focusing on the segmental or semantic features (i.e., *Does the item belong to the verb or noun group?*). Alternatively, focusing on the acoustic features also allowed classification, because typical nouns will have descending pitch and typical verbs will have ascending pitch.

It was argued that poor readers intuitively used an acoustic strategy because they accomplished the task with shorter RTs than the good readers, who presumably used a segmental strategy because good readers automatically accessed the lexicon when they encountered a strong vowel in word-initial (trochaic) position. The lexical access and classification of the word as either a “thing” or an “action” added to the response latencies of the words. As such, good readers also showed frequency effects as proof that they utilised the lexicon to categorise words. This is one of the few studies where poor readers showed better performance than good readers did. A literature review shows that the results are novel and future research is needed to confirm this finding through replication.

In Experiment 6, the target items were minimal pairs in a primed auditory lexical decision task. The stimuli were presented with the prime and target having contrastive stress. However, deciding if the target was a word could be achieved by focusing on the segmental properties only and processing the items as homophones and this is what good readers did. Good readers ignored the suprasegmental features, and thus did not anticipate any contrastive “pattern”; nor did they use the pattern to their advantage. Poor readers, however, may have focused on the words acoustic properties, and processed the items as either iambic or trochaic words. These experiments suggest that poor readers explicitly incorporate an acoustic strategy in spoken word recognition and are more sensitive to lexical stress properties of the stimuli to categorise or identify spoken words.

Good and Poor Readers attending to acoustic properties

Like Experiments 3 and 6 that focused on the explicit use of acoustic information in categorizing a sound or deciding if the a sound was a word or not, Experiments 4 and 5 focused on the explicit use of suprasegmental processing by good and poor readers. The stimulus items were minimal pairs (eg. RECord and reCORD) and poor and good readers had to decide the temporal order of verb and noun presentations in a temporal order categorization task (Experiment 4); and participants had to decide whether presentations were identical or similar in a same/difference task (Experiment 5). English listeners can exploit suprasegmental stress cues in word recognition if they are given the opportunity. Although good readers do not tend to explicitly use suprasegmental features (Cutler, 2008), Experiments 4 and 5 “forced” both types of readers to attend explicitly to acoustic properties.

Experiment 4 has increased the task demands by assessing the readers’ responses to spoken minimal pairs in a temporal order judgement task to categorize nouns and verbs. The need to attend to items at the pre-lexical level was now required by both poor and good readers and iambic items were recognised faster than trochaic by poor and good readers alike. Our results are supported by the finding of Carter and Clopper (2002), who found that children’s strategy for word recognition differs from adults (see introduction for Experiment 6). In particular, they have difficulty processing word-initial information, and it seems in this case when the task required acoustic information processing, the children preferred iambic items.

Walley (1988) in a non-speeded lexical decision task, found that children were less able than adults to use word initial information. There appears to be an iambic strategy when the processing is phonological (Monaghan et al., 2003, 2005) and for this reason both groups of readers identified iambic items faster than trochaic items in Experiment 4.

Of interest in Experiment 5 was the response of poor and good readers to a same/different task where the stimulus items were also minimal pairs. Like Experiment 4, the task could be accomplished with an acoustic strategy only. Serniclaes and colleagues (Bogliotti et al., 2008; Serniclaes, Van Heghe, Mousty, Carré, & Sprenger-Charolles, 2004; Sprenger-Charolles, Colé, & Serniclaes, 2006) predicted poor readers are better at distinguishing variances within a single phoneme, in particular allophones. The extrapolation from allophones to variation in minimal pairs may require further research as this experiment focuses on the suprasegmental differences within minimal pairs (a grammatical category). However, what the work of Serniclaes and colleagues suggests is that poor readers are still affected by their sensitivity to contrasts, after the first year when according to Aslin et. al (1998) they should have lost this ability. It appears that the poor readers processed same and different items acoustically, because minimal pairs vary in their acoustic properties only. This sensitivity to and faster processing of lexical stress variation within the contrastive condition (see **Table 14**) resulted in poor readers not showing any difference between same and contrastive items. Good readers, on the other hand, showed the expected difference in same and different presentations. This result again supports the notion that poor readers are indeed more sensitive to suprasegmental features, or at least are doing the task using suprasegmental information.

8.5 Lexical decision tasks

Apart from some earlier conference papers by Yelland (1993, 1995) regarding the use of “go/nogo” lexical decision task with children, not much has happened since in this domain. Moret-Tatay and Perea (2011) lament the fact that this is an area that requires further research and have published a recent paper on the suitability of the “go/nogo” lexical decision task for developing readers. They found the “go/nogo” lexical decision task very suitable for use with children. It showed faster response latencies, less variability (i.e., less noise) and fewer errors when compared to the “yes/no” lexical decision task.

There are a few differences between spoken word recognition and orthographic studies (Gomez, Ratcliff and Perea (2007), in particular the word onset. In orthographic studies (Gibbs & Van Orden, 1998; Hino & Lupker, 2000; Hino, Pexman, & Lupker, 2006) the word onset starts with the very first letter, whereas spoken iambic words have a same start at word onset but the word is only fully recognised after some retrospective processing. Thus in a “go/nogo” lexical decision task using spoken words, the “go/nogo” lexical decision task using iambic words might not show the expected faster processing that’s evident in the orthographic “go/nogo” lexical decision task. A review of the literature indicates that this is the first time sensitivity to suprasegmentals was assessed using a "go/nogo" lexical decision task with children. In addition, like Experiment 3, this task is another that needs further study and replication, particularly using spoken disyllabic words.

In Experiment 1 and 2, the task demands between the "go/nogo" lexical decision task and the "yes/no" lexical decision task were not different in terms of response latencies, except for adults using trochaic words (see Experiment 1). This result matches that of the orthographic studies (Gomez et al., 2007; Moret-Tatay & Perea, 2011; Perea et al., 2002) as the word onset for trochaic items is not that different to orthographic stimulus items. The "go/nogo" lexical decision task was validated in Experiments 1 and 2, and used particularly for Experiment 3. The "go/nogo" lexical decision task also produced fewer errors than the "yes/no” lexical decision task for the adults and children in Experiments 1 and 2.

8.6 Frequency

To confirm the sensitivity to lexical stress independent of lexical access, word frequency was manipulated and used as a principal indicator of the extent to which lexical information was contributing to the task response (frequency effects expected) or not. Good readers and adults showed frequency effects in Experiments 1, 2 and 3, suggesting that lexical information was a primary driver of the lexical decision. Poor readers showed no frequency effects in Experiments 2 or 3, suggesting that lexical information was masked by other information in the responses generated even though in Experiment 2 there was no RT difference between the two groups, and in Experiment 3 poor readers were actually faster to make categorisation judgements. Experiments 4 and 5 also did not show frequency effects, except for an anomaly in Experiment 5 for poor readers at 50ms ISI.

In the lexical decision tasks in Experiment 1 and 2, the items showed standard frequency effects, with high-frequency items having shorter response latencies and fewer errors. However, there were exceptions, in particularly, the low-frequency iambic verbs, which fared better than some trochaic items, suggesting that not all trochaic items result in better response latencies (see typicality). Adults showed frequency effects for trochaic items only; the good readers showed frequency effects for trochaic and iambic items; and poor readers showed no frequency effects at all.

In this thesis it is assumed that not getting frequency effects could be due to participants directing their attention to sub-lexical processing and therefore not relying on lexical code/access which is modulated by frequency (Balota & Spieler, 1999). However, there are instances when the repetitive nature of the stimulus items creates expectancy through a recency effect, which undermines the frequency effect. For example, in Experiment 6, where the same minimal pairs appeared 8 times.

8.7 Reader Lexical Stress Bias

Adults and good readers have a trochaic bias, as a strong first syllable automatically initiated lexical access (Mattys, 1997b). It appears, therefore, that good readers have a trochaic bias when processing items at the lexical level (Experiment 2). However, in Experiment 4, both poor and good readers performed better using an iambic strategy when primarily processing acoustic pre-lexical information. In fact other researchers have also found similar results, which were either ascribed to the participant's native language other than English (Arciuli & Cupples, 2004) or gender (Chiarello, Liu, Shears, & Kacinik, 2002). Yeni-Komshian et. al. (2001) argued that the iambic bias of Korean-English bilinguals is because Korean has a more prominent iambic structure. Much of the research suggests that trochaic items have an advantage. The difference appears to be a trochaic preference when the lexicon is accessed (Gow & Gordon, 1995), and an iambic strategy when the processing is phonological (Monaghan et al., 2003, 2005) in the case of good readers. However, it appears that poor readers vary their strategy to the task at hand whether lexical decision (Experiment 2 and 6) or grammatical classification (Experiment 3).

8.8 Ecology and recommendation

A principal finding is poor readers are more sensitive to lexical stress, poor readers did better than good readers when they had to recognise single items (Experiment 3) that showed typical stress placement for their word class. Poor readers are more sensitive to the acoustic/phonetic properties of the words, and depending on the task at hand this ability may assist or it may interfere with processing words. Creating and relating a phoneme to grapheme is problematic and the time taken to regularize phonemes delays reading (see RAN tasks in introduction). However, when a task could be accomplished using acoustic/phonetic processing poor readers seem to excel, such as in experiment 3, above.

The attention given to phonetic/acoustic information may affect the decoding processes when reading words. Werker and Tees (1995) have suggested that the ability to discern every possible language contrast is a capability that is only useful in the first year of life; thereafter, the listeners language sounds coalesced into a set number of phonemes. From this study it appears that poor readers retains this ability to discern contrasts, which interferes with decoding or as Ramos (2001) states it creates fuzzy representation between the phoneme-grapheme correspondences. If the representations are fuzzy, one expects that the poor reader would recalculate some phonemes whenever they read, and this recalculation or regularization causes poor readers to be slower at reading.

When teaching new words or concepts, it could benefit the poor readers if the items were presented and grouped by category rather than mixing (contrasting) words.It would be prudent to teach poor readers to use capitalizations (or another form of diacritics) to show lexical stress at the word level. Suprasegmentals could be taught using a type of diacritic system in English. The efficacy of reading sentences such as “WRITten ENGlish and SPOKen ENGlish BOTH FALL ROUGHly INto an iAMbic PATtern”. Furthermore, this researcher echoes the call by others (Arciuli & Cupples, 2006; Mattys, 1997b; van Donselaar et al., 2005), that existing word recognition models should incorporate suprasegmental processing.

This research underscores the suitability of using a "go/nogo" lexical decision task with a child population to measure their sensitivity to lexical stress. In particular, the results showed that a "go/nogo" lexical decision task produced fewer errors than the "yes/no" lexical decision task. Therefore, as an experimental paradigm the "go/nogo" lexical decision task is recommended for specific language impaired children and their normal achieving peers.

8.9 Limitations

Number of poor readers

I am grateful to the respective education departments who gave permission for the research to be conducted at their schools and the parents who gave consent for their children to participate. The children were recruited and then assessed using the TOWRE reading test (Torgensen et al., 1999). The children who were in the lower 25-percentile were deemed poor readers. This stringent criterion set by Torgensen at. al and Metsala (1997) resulted in very few poor readers participating in these experiments. Some of the same children participated in experiments 4, 5 and 6; however, care was taken to avoid order and repetition effects by spacing these experiments over a 6-month period.

Assessment environment

The environment for assessing adults in Experiment 1 was ideal. The results were collected in sound attenuated rooms where external sounds were blocked out. Although all care was taken to assess children in a quiet area at school, the children had to be visible at all times to school staff whilst being assessed. This situation was not always ideal and on occasion external sounds did distract some of the participants. This less than ideal situation also prevented the use of other experimental paradigms, in particular the use of a naming task. Except for the few occasions where external noise was a distracter, all of the research was conducted in a relatively quiet environment. The similarity between the results of the children and adults in Experiments 1 and 2 shows that the environments did not detract significantly in terms of data collection.

Other word recognition factors

There are a few factors that influence word recognition such as the age of acquisition (Smith, Turner, Brown, & Henry, 2006; Walley & Metsala, 1992; Zevin & Seidenberg, 2002), imageability (Monaghan & Ellis, 2002; Pavio, Yuille, & Madigan, 1968; Strain, Patterson, & Seidenberg, 1995, 2002) and concreteness (Gilhooly & Logie, 1980; Nation, Adams, Bowyer Crane, & Snowling, 1999). Verbs are also less imageable (Chiarello, Shears, & Lund, 1999) when compared to nouns as their meaning may be more dependent on the context in which they occur (Gentner, 2006).

Minimal pairs may be similar orthographically RECord (pronounced 'rekOd) and reCORD (pronounced rI'kOd), apart from the differences in stress position, some of these words will have minimal spoken variations A word like ADDICT is pronounced as '&dIkt as a trochaic noun and @'dIkt as an iambic verb. The apostrophe denote stress placement, see the Phonetic Symbols used in the Dictionary (Coltheart, 1981). The principal reason for not controlling for these factors was the difficulty to find a sufficient number of spoken minimal pairs that also matched these additional criteria. The difference in the use of a schwa /@/, as explained in the introduction on metrical stress in the introduction, may also influence the perception of the word, especially when the vowel is in the word initial position. This initial-vowel position influence on word recognition is further explained in the next section.

Confound in Experiment 1

If one extends the argument that the list composition sways the processing mechanism to be either predominantly pre-lexical or lexical (Connine et al., 1993), then the iambic biases encountered in Chiarello et. al (2002) and Monsell (1989) could be due to more items having a vowel in the word-initial position (e.g., amend, annoy, attack), which according to Kelly (2004) are mostly iambic words. Kelly (2004) analysed the MRC database (Coltheart, 1981) and showed that disyllabic words with vowel onset are 64% likely to be iambic. For example, Monsell et. al's (Experiment 3, 1989) data showed that 11 of their high-frequency stress-final words start with a vowel and 10 of their low-frequency words start with a vowel as well. Of the 20 stress final Low-Frequency words, 9 were typical verbs. Chiarello et. al's (2002) results for their first task, where women were better at recognizing verbs, 11 disyllabic verbs (20% of items) started with a vowel; for their second task, 16 disyllabic verbs (29% of items) started with a vowel. In Experiment 1 and 2 above, 15 disyllabic verbs (50% of items) started with a vowel. This is a confound and it is a task that could be undertaken for future research.

In this thesis, the stimulus items in experiment 1 and 2 were not exclusively nouns or verbs; some could be both verb and noun and some could be adjectives. For example, the word PROCESS is either a verb or a noun. However, the strong typicality findings suggest that adult and good listeners heard the items in the proper context that is low-frequency iambic verbs were processed faster (see *Figure 10*).

Recording of stimuli

Another factor is the researcher, who has a non-Australian accent, recorded the stimuli items while conforming to the Australian pronunciation of words. This is perhaps why the lexical decision tasks showed such robust typicality and frequency effects. Arciuli and Cupples (2004) have shown that non-native English speakers were sensitive to prosodic information. Perhaps the reverse is true, when an English speaker hears a foreign accent; they attend more too prosodic information hence the robust typicality effects. This is a topic for further study.

8.10 Summary

In summary, these six experiments clearly show that poor readers are sensitive to processing suprasegmentals, in particular lexical stress, and that there are clear differences between adults and children, and between good and poor readers when processing lexical stress.

Good readers process lexical stress much the same as adults, except they are slower. Good readers also processed trochaic items better than iambic items, when the task demand and working memory load were manageable. On the other hand, poor readers seemed to prefer using lexical stress explicitly, even on tasks when it is not required.

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Appendix A

Table 21

Items used in experiment 1 and 2.

Verb			
Iambic		Trochaic	
aDOPT	aCCEPT	BARgain	ANswer
aMEND	aGREE	CANcel	CHOsen
aMUSE	aPPEAR	CHUCkle	COver
aNNOY	aTTACK	ENvy	ENter
aPPLAUD	beGIN	GAMble	FOllow
aWAKE	beLIEVE	PARdon	LIsten
conFUSE	creATE	PUnish	MEAsure
doNATE	desTROY	RECkon	Offer
eJECT	enJOY	REScue	PROcess
oBEY	esCAPE	RUin	QUIet
oFFEND	forGET	SHOvel	REAlize
preTEND	preVENT	SWAllow	TRAvel
reCEIPT	reMOVE	VAnish	VIsit
reLAX	reSPECT	WANder	WELcome
diVIDE	reTURN	POIson	WONder

Noun			
Iambic		Trochaic	
aCCORD	aDDRESS	ANkle	BAby
aLLOY	aMOUNT	Apple	BOttle
anTIQUE	aWARD	ATHlete	CAPtain
arCADE	beLIEF	BUtcher	CAttle
aRRAY	deVICE	BUtton	CHAPter
caDET	diSEASE	KItten	COffee
carTOON	disPLAY	MANsion	DOCtor
ciGAR	esTATE	MONkey	FEmale
deCEIT	exPENSE	OYSter	HUSband
disMAY	hoTEL	ROcket	KITchen

doMAIN	maCHINE	SOfa	MARket
inTENT	maRINE	SYMptom	SHELter
raPPORT	poLICE	TIger	STAtion
reVENGE	rePORT	TOpic	TEAcher
saLOON	suPPLY	TRUMpet	TRAffic

Table 22

Adults RTs and Errors

		Yes/No Lexical Decision								Go/NoGo Lexical Decision								
RT=1, Error=2	Sex	IambicVerbLF	IambicVerbHF	TrochaicVerbLF	TrochaicVerbHF	IambicNounLF	IambicNounHF	TrochaicNounLF	TrochaicNounHF	GIambicVerbLF	GIambicVerbHF	GTrochaicVerbLF	GTrochaicVerbHF	GIambicNounLF	GIambicNounHF	GTrochaicNounLF	GTrochaicNounHF	Age: months
1	m	777	835	809	732	859	811	871	804	836	911	887	788	947	843	861	768	252
1	m	764	878	805	768	822	848	882	716	848	945	862	887	1030	873	867	794	264
1	f	748	768	778	730	839	699	742	755	708	760	765	727	844	757	804	732	276
1	f	838	931	894	842	884	837	816	752	817	952	862	836	963	867	732	765	300
1	f	828	941	929	794	940	862	839	888	959	961	974	958	1050	1001	895	795	324
1	f	762	783	880	751	879	737	785	753	737	769	847	687	786	783	798	694	384
1	m	694	681	742	658	792	715	688	645	702	717	747	655	767	700	726	676	384
1	f	758	817	776	741	865	766	793	690	750	829	773	724	817	768	779	750	396
1	f	842	929	869	876	962	869	871	808	870	944	936	858	934	870	799	823	408
1	f	607	682	782	700	781	674	719	680	614	702	681	655	700	681	651	625	408
1	m	1020	979	959	939	1082	947	836	873	970	997	994	898	1016	939	925	896	444
1	f	715	757	765	718	796	792	715	734	754	823	821	711	849	814	728	720	504
1	m	780	790	792	738	794	795	804	732	680	725	745	670	790	686	710	668	504
1	f	888	882	901	854	962	870	969	869	731	792	817	777	822	873	800	665	528
1	f	818	844	895	784	919	811	814	779	816	912	909	752	860	882	835	761	660
1	m	722	813	821	764	884	815	778	752	703	734	780	690	855	759	752	698	672
1	m	806	836	926	815	931	834	909	823	758	887	849	834	856	834	800	707	708
2	m	0	0	6.7	0	6.7	0	6.7	0	0	0	0	0	6.7	0	0	0	252
2	m	0	0	0	0	0	0	6.7	0	0	0	0	0	0	0	0	0	264

		Yes/No Lexical Decision								Go/NoGo Lexical Decision								
RT=1, Error=2	Sex	IambicVerbLF	IambicVerbHF	TrochaicVerbLF	TrochaicVerbHF	IambicNounLF	IambicNounHF	TrochaicNounLF	TrochaicNounHF	GIambicVerbLF	GIambicVerbHF	GTrochaicVerbLF	GTrochaicVerbHF	GIambicNounLF	GIambicNounHF	GTrochaicNounLF	GTrochaicNounHF	Age: months
2	f	6.7	6.7	0	6.7	0	6.7	6.7	0	6.7	0	6.7	13	0	0	20	0	276
2	f	0	6.7	0	6.7	6.7	0	7.1	0	0	0	6.7	0	6.7	0	0	0	300
2	f	0	0	0	6.7	0	6.7	0	0	0	0	13	0	6.7	0	0	0	324
2	f	6.7	0	20	20	0	6.7	6.7	6.7	0	0	6.7	6.7	6.7	0	7.1	0	384
2	m	0	6.7	13	0	26.7	6.7	13	6.7	0	0	6.7	0	6.7	0	0	0	384
2	f	0	0	7.1	6.7	13.3	13	20	6.7	0	0	6.7	0	0	0	6.7	0	396
2	f	0	0	0	0	13.3	6.7	13	0	0	0	0	0	6.7	0	7.1	0	408
2	f	0	6.7	0	6.7	13.3	0	13	0	0	0	6.7	0	0	0	6.7	0	408
2	m	6.7	0	0	13	0	0	6.7	0	0	0	7.7	0	7.7	0	0	0	444
2	f	0	0	6.7	0	0	0	0	0	0	0	0	0	6.7	0	6.7	0	504
2	m	0	6.7	6.7	6.7	6.7	0	13	0	0	0	6.7	6.7	0	0	0	0	504
2	f	6.7	13	14	6.7	13.3	29	47	0	0	6.7	13	0	0	13.3	6.7	0	528
2	f	0	0	0	6.7	6.7	0	6.7	0	0	0	0	0	6.7	0	0	0	660
2	m	6.7	0	6.7	6.7	6.7	0	13	0	7.1	0	6.7	0	0	0	0	0	672
2	m	0	0	13	6.7	6.7	0	6.7	0	0	0	0	0	0	0	0	0	708

Table 23

Child RTs and Errors

		Yes/No Lexical Decision								Go/NoGo Lexical Decision										
Type	Sex	IambicVerbLF	IambicVerbHF	TrochaicVerbLF	TrochaicVerbHF	IambicNounLF	IambicNounHF	TrochaicNounLF	TrochaicNounHF	GIambicVerbLF	GIambicVerbHF	GTrochaicVerbLF	GTrochaicVerbHF	GIambicNounLF	GIambicNounHF	GTrochaicNounLF	GTrochaicNounHF	months	Participants	Reader (Y = Good)
1	m	917	932	963	848	931	999	919	956	1001	1059	977	986	1026	993	888	935	123	1	N
1	m	1109	1172	1135	1065	1219	1058	1069	1045	964	1129	1084	1013	1118	1021	980	964	124	2	Y
1	m	1034	985	1044	1031	1028	946	891	911	890	856	857	835	984	945	831	961	123	3	Y
1	f	897	962	915	923	1004	903	924	866	952	928	1041	893	1080	970	926	880	118	4	Y
1	m	972	938	1009	933	1099	902	913	892	876	905	929	897	916	1007	801	794	120	5	N
1	f	1159	1152	1174	1108	1191	1141	971	1104	1122	1038	1075	960	1123	1127	993	1059	135	6	N
1	m	995	1011	1055	956	1017	1015	852	980	929	993	1056	994	963	948	951	895	140	7	N
1	f	869	850	858	835	872	846	793	782	844	884	851	840	908	866	820	764	129	8	Y
1	f	1077	1058	1085	1026	1154	1058	882	921	1050	1082	931	953	1097	978	924	911	128	9	Y
1	f	878	851	865	820	951	802	804	849	902	892	915	807	947	944	882	851	128	10	Y
1	m	823	863	853	845	865	815	807	757	802	838	842	819	853	895	786	732	133	11	Y
1	f	1098	1155	1179	1151	1127	1120	1086	1109	969	1094	1053	947	1201	1042	978	921	137	12	Y
1	f	897	931	967	908	995	990	877	863	949	1017	997	936	1010	990	930	899	130	13	Y
1	f	906	937	920	847	961	923	924	884	816	850	873	795	937	822	818	769	132	14	Y
1	m	984	1048	1093	967	1095	918	982	935	1091	1162	1004	1169	1007	1036	997	1162	122	15	N
2	m	8	0	14	13	46	0	7	13	14	0	8	0	27	7	0	0	123	1	N
2	m	0	0	0	0	0	0	29	7	0	0	0	0	0	0	7	0	124	2	Y
2	m	23	13	14	0	18	13	7	20	0	7	0	0	0	0	0	13	123	3	Y
2	f	0	0	0	13	46	33	14	0	0	0	0	7	40	0	0	0	118	4	Y

		Yes/No Lexical Decision								Go/NoGo Lexical Decision										
Type	Sex	IambicVerbLF	IambicVerbHF	TrochaicVerbLF	TrochaicVerbHF	IambicNounLF	IambicNounHF	TrochaicNounLF	TrochaicNounHF	GIambicVerbLF	GIambicVerbHF	GTrochaicVerbLF	GTrochaicVerbHF	GIambicNounLF	GIambicNounHF	GTrochaicNounLF	GTrochaicNounHF	months	Participants	Reader (Y = Good)
2	m	0	0	8	13	18	20	7	13	0	0	8	13	0	7	0	0	120	5	N
2	f	0	14	8	0	0	14	0	0	0	23	9	21	10	7	0	7	135	6	N
2	m	7	0	0	20	9	0	21	20	8	7	0	0	10	8	7	0	140	7	N
2	f	7	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	129	8	Y
2	f	7	14	15	7	18	7	8	7	0	0	15	0	10	7	0	0	128	9	Y
2	f	7	0	14	0	27	7	8	13	0	0	0	7	10	0	7	0	128	10	Y
2	m	7	0	14	7	0	0	0	7	0	0	0	0	0	0	0	0	133	11	Y
2	f	0	20	17	7	73	23	9	0	8	14	7	0	56	23	8	7	137	12	Y
2	f	0	0	7	14	9	7	14	0	0	0	7	0	0	0	7	0	130	13	Y
2	f	0	0	0	0	0	13	29	0	14	7	0	0	10	0	7	0	132	14	Y
2	m	0	20	7	7	27	21	15	15	13	27	46	17	38	18	33	0	122	15	N

Table 24.

Child TOWRE Scores

Participants	months	Sight Words	Sight Age	Phonemic	Phonemic ge	Towre Score	Reader
1	123	95	10	92	8.9	25	N
2	124	103	10.9	114	13.6	74	Y
3	123	103	10.9	103	11	61	Y
4	118	108	10	105	10	70	Y
5	120	88	8.9	90	8.6	19	N
6	135	94	10	90	9	25	N
7	140	90	9.9	87	8.6	17	N
8	129	121	14.6	129	16.3	98	Y
9	128	111	12	100	10.6	67	Y
10	128	110	11.9	98	10	64	Y
11	133	117	14.3	100	11.6	74	Y
12	137	96	10.6	95	10.3	36	Y
13	130	115	13	117	14.3	89	Y
14	132	110	12.9	114	14.9	82	Y

Participants	months	Sight Words	Sight Age	Phonemic	Phonemic ge	Towre Score	Reader
15	122	96	10.3	90	8.6	25	N
1	123	95	10	92	8.9	25	N
2	124	103	10.9	114	13.6	74	Y
3	123	103	10.9	103	11	61	Y
4	118	108	10	105	10	70	Y
5	120	88	8.9	90	8.6	19	N
6	135	94	10	90	9	25	N
7	140	90	9.9	87	8.6	17	N
8	129	121	14.6	129	16.3	98	Y
9	128	111	12	100	10.6	67	Y
10	128	110	11.9	98	10	64	Y
11	133	117	14.3	100	11.6	74	Y
12	137	96	10.6	95	10.3	36	Y
13	130	115	13	117	14.3	89	Y
14	132	110	12.9	114	14.9	82	Y
15	122	96	10.3	90	8.6	25	N

Appendix B

Table 25

Items used in experiment 3.

Noun(trochaic)		Verb(iambic)	
HF	LF	HF	LF
NOvel	BIScuit	comPLETE	anNOY
MEthod	CAPtion	diRECT	reTRIEVE
NAtion	HELmet	aFFORD	orDAIN
WINdow	RUNway	imPROVE	aMAZE
SEnior	REINdeer	preFER	comPUTE
KINGdom	BURglar	mainTAIN	reCITE
KITchen	COmet	reMAIN	frusTRATE
SOlid	RAScal	reCEIVE	coLLIDE
TEnnis	DAMper	reDUCE	exPLODE
RAILway	CARton	aTTACK	bapTIZE

Table 26

Child RTs and Errors

Type	sex	HF Noun	LF Noun	HF Verb	LF Verb	Subject	TOWRE	Reader
1	F	1219.8	1184.8	1068.1	1124.2	1	4	2
1	M	1027.1	927.5	986.5	1006.9	2	23	2
1	F	1076.3	1059.8	1157.8	1200.5	3	13	2
1	M	1070.7	889.8	985.1	802	4	23	2
1	F	952.2	1027.6	1144.8	1106	5	7	2
1	F	1210.5	1241.6	1063.8	1103.2	6	32	1
1	F	919.2	837.7	867.4	854	7	7	2
1	M	1037.1	1143.2	1191.5	1189.4	8	61	1
1	M	1135.3	1212.5	1114.6	1209.6	9	42	1
1	M	1123.1	1113.7	1233.1	1271.8	10	93	1
1	M	1167.9	1250	1410.8	1285.9	11	48	1
1	F	939.2	951.6	1124.5	1151	12	79	1
1	F	1204.1	1289.9	1425.7	1343.6	13	32	1
1	F	1025	1100.6	1070.1	1104.2	14	92	1
1	M	1148.9	1132.2	1052.4	1055.5	15	74	1
1	M	1082.6	1017.9	1119.6	1182.3	16	89	1
1	M	1207.2	1139.7	1031.4	1098.8	17	79	1
1	F	1034	1174.5	1032.7	911.5	18	9	2
2	F	0	10	0	10	1	4	2
2	M	0	0	14.3	30	2	23	2
2	F	25	60	12.5	12.5	3	13	2
2	M	10	12.5	0	0	4	23	2
2	F	10	20	11.1	10	5	7	2
2	F	0	0	11.1	22.2	6	32	1
2	F	20	0	10	22.2	7	7	2
2	M	25	25	10	16.7	8	61	1
2	M	28.6	11.1	12.5	22.2	9	42	1
2	M	11.1	0	10	0	10	93	1
2	M	12.5	25	40	33.3	11	48	1
2	F	0	0	0	30	12	79	1
2	F	16.7	22.2	40	42.9	13	32	1
2	F	11.1	22.2	10	22.2	14	92	1

Type	sex	HF Noun	LF Noun	HF Verb	LF Verb	Subject	TOWRE	Reader
2	M	11.1	11.1	0	11.1	15	74	1
2	M	30	11.1	10	25	16	89	1
2	M	14.3	20	12.5	20	17	79	1
2	F	0	11.1	10	0	18	9	2

Appendix C

Table 27

Items used in experiment 4

Noun(trochaic)		Verb(iambic)	
HF	LF	HF	LF
REcord	ADvert	reCORD	adVERT
ACcent	DIgest	acCENT	diGEST
OBject	CONsole	obJECT	conSOLE
PROgress	REplay	proGRESS	rePLAY
CONflict	COMpress	conFLICT	comPRESS
PROject	REprint	proJECT	rePRINT
CONtent	IMplant	conTENT	imPLANT
PERfect	ADdict	perFECT	adDICT
TRANSfer	ANnex	transFER	anNEX
CONtract	REfund	conTRACT	reFUND

Table 28

Child RTs and Errors

Subject	sex	HF Noun	HF Noun Err	LF Noun	LF Noun Err	HF Verb	HF Verb Err	LF Verb	LF Verb Err	TOWRE	Reader
1	F	2326.16	4	2369.98	3	1323.66	6	1459.94	4	4	2
2	M	1140.24	4	1232.9	4	1479.47	4	1704.18	4	23	2
3	F	2191.69	3	1857.47	7	1525.9	6	1641.95	5	13	2
4	M	1427.37	7	1309.68	4	1100.11	6	983.87	7	23	2
5	F	1317.09	6	1908.68	4	1482.13	5	1400.05	2	7	2
6	F	1582.22	6	1256.03	3	1167.55	6	1184.66	7	32	1
7	F	1038.63	5	1148.4	5	1065.8	5	1245.56	5	7	2
8	M	1623.82	5	1737.67	4	1217.19	0	1080.02	1	61	1
9	M	1504.48	5	1821.4	6	1380.4	5	1400.96	2	42	1
10	M	1614.93	3	1388.76	4	1469.45	5	1414.42	5	93	1
11	M	2125.89	3	1723.98	9	1455.89	2	1463.77	4	48	1
12	F	1374.99	5	1626.83	5	1341.16	6	1724.26	1	79	1
13	F	1827.18	4	1530.42	5	1716.62	5	1665.27	8	32	1
14	F	1285.06	4	1264.68	6	1503.55	1	1375.08	4	92	1
15	M	2172.17	6	1837.71	3	1860.75	4	1652.13	6	74	1
16	M	1513.81	3	1532.75	4	1495.3	4	1473.49	2	89	1
17	M	1402.49	1	1718.51	5	1378.12	5	1316.9	4	79	1
18	F	1503.99	6	1417.83	4	1450.57	6	1492.69	4	9	2

Legend:
Reader: Poor =2, Good =1

Appendix D

Table 29

Items used in experiment 5

NOUN		VERB	
HF	LF	HF	LF
CONflict	SEGment	conFLICT	segMENT
PROject	COMpact	proJECT	comPACT
CONtent	CONtest	conTENT	conTEST
PERfect	INsert	perFECT	inSERT
IMpact	INsult	imPACT	inSULT
CONtract	REbel	conTRACT	reBEL
UPset	DIGest	upSET	diGEST
SURvey	EScort	surVEY	esCORT

Table 30

Child RTs and Errors for 500 ms ISI

		Identity Pairs				Contrastive Pairs						
type	sex	HF Noun-Noun	LF Noun-Noun	HF Verb-Verb	LF Verb-Verb	HF Noun-Verb	LF Noun-Verb	HF Verb-Noun	LF Verb-Noun	Subject	towper	reader
1	F	1143.7	1142.9	1098.4	1135.6	1088.8	1080.3	1203	1118.8	1	92	1
1	M	728.3	649.8	761	690.5	786.5	965.9	824	864	2	39	2
1	F	941.9	935	981	1041.5	1067.5	1014.9	896	1119.9	3	9	2
1	F	1220.1	1228	1238.9	1279.2	1182.3	1269.1	1345	1300	4	45	1
1	F	864.4	864.3	966.1	928.2	972.2	958.6	1069	944.8	5	13	2
1	M	1123.8	1131.2	1144.2	1136.6	1121.4	1200.2	1126	1129.5	6	89	1
1	F	1162.5	1147	1192.5	1222.1	1138.1	1167.7	985	1197.2	7	9	2
1	F	1125.5	1018.3	1047.5	1020.1	1136.3	1102.9	1194	1152.3	8	32	2
1	M	1156.8	1188.1	1172.3	1120.7	1170	981	1082	1014.5	9	23	2
1	F	1189.7	1074.7	1102	974.3	1134.2	1148	1102	1185.9	10	13	2
1	M	1121.6	1073.9	980.5	1044.9	1127.3	1138.3	990	1080.8	11	42	1
1	M	962.7	927	958.8	895.1	887	1012.1	949	890.4	12	61	1
1	M	930.2	943.5	909.2	927	1013.8	1065.7	1057	1050.9	13	52	1
1	M	912.5	719.1	758.4	695.6	838.5	1042	1056	744.4	14	36	2
1	M	853.2	909	804.5	957.4	934.9	867.6	919	941.2	15	95	1
1	F	1085.9	1070.7	1038.5	1070.5	1172.5	1142.1	1107	1081.9	16	39	2
1	M	917.5	1129.1	1044.8	989.4	998.6	960.2	989	974.4	17	93	1
1	M	1131.7	1159.1	1195.6	1179.2	1190.8	1123.5	1197	1147.1	18	1	2

		Identity Pairs				Contrastive Pairs						
type	sex	HF Noun-Noun	LF Noun-Noun	HF Verb-Verb	LF Verb-Verb	HF Noun-Verb	LF Noun-Verb	HF Verb-Noun	LF Verb-Noun	Subject	towper	reader
1	M	1070.3	1161.3	1066.4	1007.3	979.8	1057.2	1094	1008.2	19	61	1
1	M	1184.9	1160.3	1148	989.9	1052.6	1098.4	1160	1217.9	20	74	1
1	M	902.6	979.9	937	1105.1	1038.8	1064.1	963	1010.6	21	23	2
1	M	844	899.6	876.1	930.4	1044	1066.1	968	988.8	22	48	1
1	M	1179.6	1301.5	1086.4	1257.5	1273.2	1203.7	1173	1186.4	23	93	1
1	F	964.9	941.1	950.9	1074.8	940.8	1121.8	1076	1132.3	24	7	2
2	F	0	12.5	37.5	0	0	0	13	14.3	1	92	1
2	M	25	0	0	0	25	25	25	12.5	2	39	2
2	F	12.5	0	0	0	12.5	0	13	25	3	9	2
2	F	57.1	14.3	0	42.9	50	14.3	50	25	4	45	1
2	F	0	0	0	0	0	0	0	0	5	13	2
2	M	0	0	0	0	12.5	25	29	0	6	89	1
2	F	28.6	0	0	14.3	14.3	28.6	43	37.5	7	9	2
2	F	0	12.5	12.5	12.5	25	25	14	14.3	8	32	2
2	M	14.3	0	50	25	25	12.5	38	0	9	23	2
2	F	12.5	0	0	33.3	12.5	25	25	14.3	10	13	2
2	M	0	0	12.5	0	0	0	0	12.5	11	42	1
2	M	0	12.5	0	12.5	12.5	0	0	0	12	61	1
2	M	0	0	12.5	12.5	25	14.3	43	37.5	13	52	1
2	M	14.3	33.3	33.3	16.7	57.1	57.1	67	71.4	14	36	2
2	M	0	0	0	0	0	0	0	0	15	95	1
2	F	0	0	0	0	12.5	0	0	0	16	39	2
2	M	14.3	0	12.5	0	12.5	12.5	14	14.3	17	93	1
2	M	14.3	14.3	0	14.3	0	0	14	0	18	1	2
2	M	0	0	0	0	0	0	0	12.5	19	61	1

		Identity Pairs				Contrastive Pairs						
type	sex	HF Noun Noun-	LF Noun Noun-	HF Verb Verb-	LF Verb Verb-	HF Verb Noun-	LF Verb Noun-	HF Noun Verb-	LF Noun Verb-	Subject	towper	reader
2	M	57.1	50	75	42.9	33.3	37.5	25	71.4	20	74	1
2	M	12.5	12.5	0	33.3	37.5	62.5	38	50	21	23	2
2	M	12.5	25	28.6	25	0	50	38	37.5	22	48	1
2	M	0	33.3	25	12.5	14.3	16.7	38	28.6	23	93	1
2	F	75	75	12.5	25	37.5	50	25	28.6	24	7	2

Table 31

Child RTs and Errors for 50 ms ISI

		Identity Pairs				Contrastive Pairs						
type	sex	HF Noun Noun-	LF Noun Noun-	HF Verb Verb-	LF Verb Verb-	HF Verb Noun-	LF Verb Noun-	HF Noun Verb-	LF Noun Verb-	Subject	towper	reader
1	F	1098.8	1167.3	1028.5	1106.6	1159.8	1068.4	1010.7	1049.9	1	92	1
1	M	924.9	950.1	1001.2	946.2	961.1	1007.1	1046.8	982.9	2	39	2
1	F	1115.4	1125.5	1038.5	1102.7	1035.5	1066.8	1102.1	1285.1	3	9	2
1	F	1194.4	1181.8	1280.8	1253.1	1311.4	1357.3	1206.9	869.7	4	45	1
1	F	972.6	1097.7	970.4	981.9	1039.5	1033.1	933	995.8	5	13	2
1	M	1085.4	1017.1	1184	1052.4	1149	1125.7	1251.1	1071.4	6	89	1
1	F	1050.7	959.8	934.5	1056	1047.9	1075.4	1115.6	1050.7	7	9	2
1	F	792	806.2	896.5	922.4	886.9	954.2	979.7	854.4	8	32	2
1	M	1088.2	999.6	1083.7	1150.4	1084.5	1124.7	1034	1042.1	9	23	2

		Identity Pairs				Contrastive Pairs						
type	sex	HF Noun-Noun	LF Noun-Noun	HF Verb-Verb	LF Verb-Verb	HF Noun-Verb	LF Noun-Verb	HF Verb-Noun	LF Verb-Noun	Subject	towper	reader
1	F	968.3	1147.5	1014.6	1186.8	879.3	972.2	995.6	848	10	13	2
1	M	1022.8	1098.3	1004.1	1052.5	1077.2	1188.6	1274.5	1093	11	42	1
1	M	1077.4	858.4	1135	894.2	1075.8	1159.1	1260.3	1012.8	12	61	1
1	M	986.8	1003.3	953.7	1294.9	967	1026.8	1223.5	1277.6	13	52	1
1	M	1080.3	1134.5	1066	1046.3	1105.4	1065.2	1154.8	1078.6	14	36	2
1	M	916.9	843.7	919.7	825.4	906.8	966.8	939.4	842.7	15	95	1
1	F	1053.5	1130.6	1206.3	1122.5	1105.7	1191.2	1129.5	1148.9	16	39	2
1	M	1056.1	1059.8	1037.9	1101	1122.9	1202.3	1066.2	1017.2	17	93	1
1	M	1061	990.6	1080.5	1078.5	940.7	954.9	1075	999.7	18	1	2
1	M	1180.2	1209.6	1179.3	1131.6	1249.6	1014.9	1178.9	1156.4	19	61	1
1	M	1194.5	980.6	993.7	1019.7	988.3	965.9	963.7	1111.9	20	74	1
1	M	1044.2	950.4	717	856.6	788.2	1043.3	811.8	905.2	21	23	2
1	M	779.6	709	903.6	807.2	803.1	754.9	879.8	911.4	22	48	1
1	M	1131.1	1141.5	1103.1	978.4	1211.4	1123.1	1086.7	970.4	23	93	1
1	F	983.6	1161	977.8	1100.9	1063.8	1152.9	1158.5	1239.1	24	7	2
2	F	0	0	0	0	12.5	0	25	14.3	1	92	1
2	M	0	0	0	0	0	0	0	0	2	39	2
2	F	25	0	0	28.6	0	0	28.6	25	3	9	2
2	F	33.3	25	71.4	50	75	40	50	83.3	4	45	1
2	F	0	0	0	0	0	0	0	0	5	13	2
2	M	0	12.5	12.5	0	37.5	25	50	12.5	6	89	1
2	F	14.3	37.5	12.5	12.5	25	37.5	12.5	42.9	7	9	2
2	F	12.5	12.5	37.5	25	37.5	28.6	25	50	8	32	2
2	M	0	14.3	37.5	50	62.5	37.5	37.5	0	9	23	2
2	F	12.5	0	42.9	28.6	12.5	37.5	37.5	62.5	10	13	2

		Identity Pairs				Contrastive Pairs						
type	sex	Noun-HF Noun	Noun-LF Noun	Verb-HF Verb	Verb-LF Verb	Noun-HF Verb	Noun-LF Verb	Verb-HF Noun	Verb-LF Noun	Subject	towper	reader
2	M	0	12.5	37.5	0	42.9	14.3	25	50	11	42	1
2	M	14.3	14.3	16.7	60	12.5	37.5	33.3	14.3	12	61	1
2	M	42.9	25	0	50	62.5	37.5	37.5	57.1	13	52	1
2	M	0	0	12.5	0	12.5	40	14.3	28.6	14	36	2
2	M	12.5	0	0	12.5	0	12.5	0	28.6	15	95	1
2	F	16.7	40	16.7	25	33.3	28.6	16.7	12.5	16	39	2
2	M	14.3	0	37.5	12.5	0	25	25	14.3	17	93	1
2	M	25	25	0	25	28.6	14.3	12.5	12.5	18	1	2
2	M	0	0	0	0	14.3	50	0	0	19	61	1
2	M	50	37.5	14.3	50	14.3	0	25	25	20	74	1
2	M	0	12.5	0	12.5	37.5	25	37.5	50	21	23	2
2	M	0	14.3	37.5	12.5	12.5	25	28.6	37.5	22	48	1
2	M	0	0	0	0	50	0	0	0	23	93	1
2	F	0	50	0	25	25	50	37.5	75	24	7	2

Legend:
Reader: Poor =2, Good =1
Type: RTs = 1, Errors = 2

Appendix E

Table 32

Items used in Experiment 6

Word Pairs							
Noun (trochaic)-Verb(iambic)		Verb(iambic)-Noun(trochaic)		Noun(trochaic)- Non-Word(iambic)		Verb(iambic)- Non-Word(trochaic)	
High-frequency Pairs							
SECond	seCOND	seCOND	SECond	SECond	bleDAB	seCOND	BLEDab
SUBject	subJECT	subJECT	SUBject	SUBject	bluRIM	subJECT	BLURim
PRESent	preSENT	preSENT	PRESent	PRESent	braNEK	preSENT	BRANek
PRODuce	proDUCE	proDUCE	PRODuce	PRODuce	briGAS	proDUCE	BRIGas
PROCess	proCESS	proCESS	PROCess	PROCess	chaPIC	proCESS	CHAPic
TRANsport	tranSPORT	tranSPORT	TRANsport	TRANsport	chaRAM	tranSPORT	CHARam
RECord	reCORD	reCORD	RECord	RECord	chiNEK	reCORD	CHINek
SUSpect	susPECT	susPECT	SUSpect	SUSpect	chuMOM	susPECT	CHUMom
INcrease	InCREASE	InCREASE	INcrease	INcrease	cloDAB	InCREASE	CLODab
OBject	objECT	objECT	OBject	OBject	cloTAY	objECT	CLOTay
PROgress	proGRESS	proGRESS	PROgress	PROgress	criBAT	proGRESS	CRIBat
ACcent	acCENT	acCENT	ACcent	ACcent	droPEW	AcCENT	DROPew
PUBlic	seCOND	beCOME	SECond	PUBlic	bloBAT	beCOME	BLOBat
LEvel	subJECT	reSULT	SUBject	LEvel	bloTAY	reSULT	BLOTay
CENtre	preSENT	deCIDE	PRESent	CENtre	broDAK	deCIDE	BRODak
MInus	proDUCE	supPORT	PRODuce	MInus	broWIN	supPORT	BROWin
FAther	proCESS	forGET	PROCess	FAther	chiPEW	forGET	CHIPew
FIgure	tranSPORT	beGIN	TRANsport	FIgure	claDAY	beGIN	CLADay
LAdy	reCORD	suGGEST	RECord	LAdy	croPAR	suGGEST	CROPar
DOCtor	susPECT	corRECT	SUSpect	DOCtor	cruSOT	corRECT	CRUSot
SUmmer	InCREASE	diRECT	INcrease	SUmmer	draBEL	diRECT	DRABel
LECture	objECT	beCAME	OBject	LECture	dreWAT	beCAME	DREWat
TItle	proGRESS	beLIEVE	PROgress	TItle	fliPAW	beLIEVE	FLIPaw

Word Pairs							
Noun (trochaic)-Verb(iambic)		Verb(iambic)-Noun(trochaic)		Noun(trochaic)- Non-Word(iambic)		Verb(iambic)- Non-Word(trochaic)	
TOpic	acCENT	misTAKE	ACcent	TOpic	freTAB	misTAKE	FRETab
Low-frequency Pairs							
FERment	ferMENT	ferMENT	FERment	FERment	driPEW	ferMENT	DRIPew
PURport	purPORT	purPORT	PURport	PURport	flaGAS	purPORT	FLAGas
CONsole	conSOLE	conSOLE	CONsole	CONsole	fleDAB	conSOLE	FLEDab
CONvict	conVICT	conVICT	CONvict	CONvict	floWAS	conVICT	FLOWas
DIScard	disCARD	disCARD	DIScard	DIScard	gleWAN	disCARD	GLEWan
INcline	inCLINE	inCLINE	INcline	INcline	kniTAP	inCLINE	KNITap
PERmit	perMIT	perMIT	PERmit	PERmit	ploDAB	perMIT	PLODab
UPlift	upLIFT	upLIFT	UPlift	UPlift	prePED	upLIFT	PREPed
COMpress	comPRESS	comPRESS	COMpress	COMpress	shiMOM	comPRESS	SHIMom
DEcoy	deCOY	deCOY	DEcoy	DEcoy	thoRIG	deCOY	THORig
INcense	inCENSE	inCENSE	INcense	INcense	whiGAS	inCENSE	WHIGas
PERfume	perFUME	perFUME	PERfume	PERfume	wraPOM	perFUME	WRAPom
BUILder	ferMENT	comMUTE	FERment	BUILder	gluMOP	comMUTE	GLUMop
COmma	purPORT	deFER	PURport	COmma	griMUN	deFER	GRIMun
BANjo	conSOLE	miGRATE	CONsole	BANjo	groWAS	miGRATE	GROWas
BUtcher	conVICT	reJOICE	CONvict	BUtcher	pluSOY	reJOICE	PLUSoy
CUStard	disCARD	disMAY	DIScard	CUStard	praMUG	disMAY	PRAMug
FEAther	inCLINE	subSIDE	INcline	FEAther	skiDAN	subSIDE	SKIDan
GUtter	perMIT	vaCATE	PERmit	GUtter	skiPEG	vaCATE	SKIPeg
KItten	upLIFT	bapTIZE	UPlift	KItten	staREN	bapTIZE	STARen
HAMster	comPRESS	narRATE	COMpress	HAMster	stuBIB	narRATE	STUBib
MUStard	deCOY	reMIT	DEcoy	MUStard	smuGED	reMIT	SMUGed
NAnny	inCENSE	diLUTE	INcense	NAnny	triGET	diLUTE	TRIGet
SUNset	perFUME	reFESH	PERfume	SUNset	whiPIG	reFRESH	WHIPig

Table 33.

Child RTs and Errors

Type	HF Noun-Verb	HF Verb-Noun	HF Base-Verb	HF Base-Noun	LF Noun-Verb	LF Verb-Noun	LF Base-Verb	LF Base Noun	Subject	Sex	TOWRE	Reader
1	1023.3	1062.5	1152.4	1062.2	1086.3	979.5	1217.3	1149.3	1	F	92	1
1	889.3	853.9	942.7	887.8	880.8	812.1	892.5	926.6	2	M	39	2
1	965.8	864.5	966.2	1013.8	1009.3	899.9	1042.6	967.9	3	F	9	2
1	1052	995.8	1120.4	1051.5	946.7	1023.1	1112.5	1056.4	4	M	39	2
1	1012	1003.5	1157.8	1085.7	1034.1	1053.6	1224.2	1215.6	5	F	45	1
1	888.1	970.6	1050.4	1115.4	1029.1	1005	1182.1	1135.2	6	F	13	2
1	930.7	944	1133	1148.6	1038.1	955.3	1196.2	1063.1	7	M	89	1
1	790.7	868.8	872.4	878.1	819.5	791.7	1068	836.1	8	F	9	2
1	1045.6	1084	1089.6	1127.2	1071.7	1077.9	1124.1	1035	9	F	14	2
1	1048.6	918	1090.7	1051.2	1051.3	910.6	1090.3	1047.4	10	M	23	2
1	979.9	920.1	1154.8	1101.7	870.1	1053.3	1129	1104.4	11	F	13	2
1	1000.1	979.1	1046.9	1060.7	1021	949.1	1039.7	1044.2	12	M	42	1
1	934.2	973	1114.4	1042.7	949.9	988.9	1151.5	1111.7	13	M	61	1
1	864.9	943.3	1035.7	1189.7	814.4	792.9	1079.7	1015.1	14	M	52	1
1	1120.9	929.7	1056.1	1057.9	999	1043.7	1100.5	1150.1	15	M	36	2
1	1205.6	1168	1204.4	1192.6	926.5	1223.1	1095.9	1048.3	16	M	42	2
1	760.6	797.2	868.9	846.6	859.4	745.7	830.2	829.1	17	M	95	1
1	985.2	1064.9	1118.6	977.4	1018	1014.7	1131.7	1090.5	18	F	39	2
1	905.2	895.5	1012.2	994.7	920.6	1019.2	1048.5	1032.2	19	M	93	1
1	1096.6	1060.5	1125.9	1283.1	1029.2	1148.2	1100.9	1103.5	20	M	1	2
1	947.4	903.4	899.9	980.4	886.1	827.8	983.8	941.2	21	M	61	1
1	985.8	994.6	1138.6	1151.6	1044.6	909.8	1045	1049.9	22	M	74	1
1	856.8	890.3	956.8	923.9	917.7	910.1	1011.2	973	23	M	79	1
1	1125.	1099.	1191.	1238.	1152.	1110.	1203.	1224.	24	F	74	1

Type	HF Noun-Verb	HF Verb-Noun	HF Base-Verb	HF Base-Noun	LF Noun-Verb	LF Verb-Noun	LF Base-Verb	LF Base Noun	Subject	Sex	TOWRE	Reader
	8	5	6	4	1	4	9	9				
1	833.1	838.7	948.3	868.5	889.8	948	1040.9	828.9	25	M	23	2
1	861	913	980.1	877.7	897.4	892.5	1106.7	1041.3	26	M	48	1
1	1097.6	948.6	1147.6	1141.8	1056.7	1033.2	1125.4	1125.8	27	M	93	1
1	939.8	837.9	1061.8	1043	1011.1	800.5	1122.9	1188.7	28	F	7	2
2	0	0	0	9.1	0	8.3	25	18.2	1	F	92	1
2	8.3	0	8.3	0	8.3	8.3	16.7	25	2	M	39	2
2	0	8.3	8.3	8.3	0	0	33.3	33.3	3	F	9	2
2	10	8.3	18.2	0	0	8.3	25	50	4	M	39	2
2	18.2	0	36.4	0	16.7	0	33.3	9.1	5	F	45	1
2	8.3	0	36.4	16.7	16.7	16.7	36.4	36.4	6	F	13	2
2	27.3	9.1	33.3	0	27.3	9.1	18.2	16.7	7	M	89	1
2	41.7	25	27.3	33.3	41.7	25	75	36.4	8	F	9	2
2	27.3	0	33.3	33.3	0	8.3	63.6	63.6	9	F	14	2
2	0	0	20	8.3	18.2	25	20	8.3	10	M	23	2
2	0	0	22.2	16.7	25	18.2	18.2	16.7	11	F	13	2
2	0	0	25	10	8.3	0	25	16.7	12	M	42	1
2	0	0	18.2	40	18.2	27.3	30	40	13	M	61	1
2	16.7	8.3	54.5	54.5	18.2	9.1	72.7	41.7	14	M	52	1
2	41.7	9.1	27.3	9.1	45.5	16.7	25	41.7	15	M	36	2
2	66.7	45.5	63.6	55.6	50	16.7	50	27.3	16	M	42	2
2	16.7	8.3	8.3	8.3	0	8.3	16.7	16.7	17	M	95	1
2	9.1	0	18.2	18.2	10	16.7	50	8.3	18	F	39	2
2	8.3	0	25	10	8.3	0	27.3	8.3	19	M	93	1
2	27.3	9.1	50	40	36.4	41.7	41.7	58.3	20	M	1	2
2	33.3	0	16.7	25	18.2	16.7	41.7	16.7	21	M	61	1
2	16.7	0	18.2	33.3	25	25	45.5	25	22	M	74	1
2	8.3	0	8.3	0	16.7	16.7	9.1	16.7	23	M	79	1
2	18.2	9.1	11.1	0	9.1	9.1	63.6	50	24	F	74	1
2	18.2	8.3	60	16.7	33.3	50	36.4	16.7	25	M	23	2
2	33.3	8.3	20	45.5	16.7	18.2	27.3	41.7	26	M	48	1
2	16.7	0	18.2	8.3	16.7	8.3	20	9.1	27	M	93	1
2	33.3	0	16.7	30	8.3	18.2	25	25	28	F	7	2

Legend:
Reader: Poor =2, Good =1
Type: RTs = 1, Errors = 2