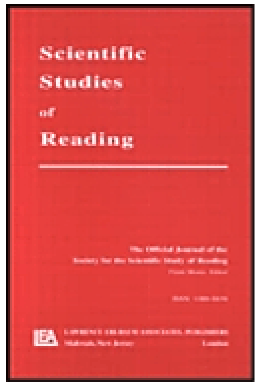

Prosodic Competence as the Missing Component of Reading Processes: Theory, Evidence and Future Research

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Abstract

Referring to the "vital parts" of speech that do not appear in print, E. B. Huey (1908/1968) described prosody in reading as "the rise and fall of pitch and inflection, the hurrying here and slowing there, what we have called the melody of speech." In this paper, we discuss the role prosody plays in reading, contextualized in the Reading Systems Framework, as a source of linguistic knowledge that impacts the orthographic system, the lexicon, and comprehension processes in tonal and non-tonal languages. Prosody at the word, phrase, and discourse levels is considered. We also review empirical evidence from experimental, longitudinal, and training studies to show the current state of knowledge about the role of prosodic competence in reading development. We conclude the paper with recommendations for future directions in research.

We begin this report with the uncontroversial assertion that reading has its roots in spoken language. For example, phonological and morphological awareness are strong predictors of decoding skill, and vocabulary and syntactic knowledge are foundational to comprehension. Our topic is an aspect of language that is somewhat less familiar to reading researchers: prosody. Prosody has been called the "rhythm and melody of spoken language" (Speer & Ito, 2009, p. 90) and the "organizational structure of speech" (Beckman, 1996, p. 21), manifested through patterns of linguistic meter, pitch changes, duration, and emphasis.

Prosody is evident in spoken language in at least three ways. At the word level, prosody is manifested through word stress, as seen in the contrast between the words *desert* and *dessert*. At the phrase level, prosody marks syntactic units by pauses, pitch changes and lengthened syllables, which can be heard in the contrast between *She said Breonna Taylor needs justice* and *She said, "Breonna Taylor needs justice"*. Finally, prosody is involved at the discourse level by accenting or emphasizing elements in the discourse that are new, surprising, or contrary relative to already established elements (e.g. ***Mary** bought that car vs Mary bought **that** car*). These examples illustrate how important prosody is in language processing; as an integral component of oral language, prosody has a central focus in domains such as language acquisition, psycholinguistics, and speech perception. Some aspects of prosody have been examined in relation to reading, but a more expansive treatment of prosody has been lacking. In this paper, we first discuss how prosody might be integrated into a theoretical model of reading that encompasses both word reading and reading comprehension. We then review empirical evidence that prosodic competence contributes to reading development. In doing so, we identify where research is still needed.

Locating Prosody in the Reading Systems Framework

We argue that prosodic competence is complex, informing many aspects of literacy development, from its earliest stages to more complex multisyllabic decoding and reading comprehension. One way to think about how prosody might be implicated in reading is to situate it in the Reading Systems Framework (RSF, Perfetti, Landi & Oakhill, 2005; Perfetti & Stafura, 2014) (see Figure 1).

Insert Figure 1 about here

Prosody in the linguistic system.

In reading research, we primarily think of phonology in relation to the units that are encoded in a language's writing system. The phoneme is the phonological primitive in alphabets; in syllabaries and logographies the critical phonological unit is the syllable (Shu, Peng, & McBride-Chang, 2008). However, suprasegmental information, (aspects of speech sound relating to pitch, duration, and amplitude that are realised *across* segmental units), is also part of phonology. The RSF situates phonology within the linguistic system, as a source of knowledge that contributes to other domains involved in reading. Metalinguistic awareness of sublexical phonology has been shown to be a strong predictor of reading (Bradley & Bryant, 1983; Ehri et al., 2001). Recently, phonological research has broadened to include suprasegmental phonology, and how it relates to reading skill. In this account we use *prosodic competence* to mean individual differences in the ability to reflect on and process speech prosody, in a manner analogous to how we conceptualise sublexical phonology. The research that we discuss here has referred to this ability by a number of different terms such as prosodic awareness (e.g., Nash & Arciuli, 2014; Chan & Wade-Woolley, 2018), prosodic sensitivity (e.g., Kim & Petscher, 2016; Whalley & Hansen, 2006), stress sensitivity (Wood, 2006; Goodman, et al., 2010), and speech rhythm sensitivity (e.g., Holliman, et al., 2010; Harrison, et al., 2018). This diversity of language does not seem to be principled; in many cases, the same type of task has been described by different terms, sometimes by the same research team. Rather than privilege any one of these terms, we adopt *prosodic competence* to encompass them.

Metalinguistic awareness of word stress is one type of prosodic competence. Studies have revealed significant associations between children's awareness of lexical stress and decoding in alphabetic languages such as English (Clin et al., 2009; Goswami et al., 2010; Holliman et al., 2010; Jarmulowicz et al., 2007; Wade-Woolley, 2016; Whalley & Hansen, 2006) and Spanish (e.g., Defior et al., 2012; Gutiérrez-Palma et al., 2009; Gutiérrez-Palma et al., 2016). Researchers investigating the independent contribution of prosodic competence to word reading in alphabetic languages describe mixed results; some report that prosodic competence does not make a unique contribution to word reading after accounting for phonological and/or morphological awareness (e.g., Deacon et al., 2018; Goodman et al., 2010; Holliman et al., 2014; Kim & Petscher, 2016). Others find that even after accounting for phonological awareness, morphological awareness, and vocabulary, individual differences in prosodic competence predict word reading ability (e.g., Defior et al., 2012; Goswami et al., 2010; Goswami et al., 2013; Gutiérrez-Palma et al., 2016; Holliman et al., 2010; Holliman et al., 2017; Jarmulowicz et al., 2007; Lin et al., 2018; Whalley & Hansen, 2006). This may be especially true for reading multisyllabic words, where correct stress placement is particularly important (Enderby et al., 2021; Wade-Woolley, 2016).

The relationship between prosodic competence and reading is further evidenced in non-alphabetic languages. For example, in Chinese lexical tone awareness represents prosodic competence important for Chinese reading analogous to the role of lexical stress in English and Spanish; variation in tone (pitch) changes word meaning. In Cantonese which utilizes a 6-tone system, /sik/ can mean colour 色 /sik1/ or to eat 食 /sik6/. Methods used to measure lexical tone awareness have included tone perception, tone discrimination, and tone production. In the tone discrimination task (e.g., Tong & McBride-Chang, 2010), students are presented with four pictures with four words and instructed to identify the one that contains a different lexical tone. Tone production, described in Li and Ho (2011), involves students producing syllables that share the same tone as the syllable presented to them. Such measures have both directly and indirectly predicted a range of Chinese reading outcomes (character reading, word recognition, sentence reading) for both Mandarin and Cantonese-speaking children (e.g., Chung et al., 2017; McBride-Chang et al., 2008; Tong, Tong & McBride-Chang, 2015; Yin et al., 2011; Zhang & McBride-Chang, 2014). The emphasis on lexical tone awareness in Chinese phonology places it central to Chinese reading development.

We find then that prosodic competence is associated with a range of reading abilities across both alphabetic and non-alphabetic languages, but the relative contributions of prosodic competence to reading may differ based on linguistic differences across languages. We expect that one reason findings are somewhat equivocal in alphabetic languages is because studies have employed different measures to assess prosody. Measuring prosodic competence is challenging because prosody applies to words, syntactic phrases, entire utterances, and discourse. A range of paradigms have been used in the reading literature, and they often assess different facets of prosody (see Table 1 for a brief description of some of the most commonly used tasks). For example, Wade-Woolley (2016) asked children to locate primary stress in a word (“where do you hear the strongest beat?”) while Jarmulowicz et al. (2007) asked children to pronounce a nonword and then to add *-ity* to it, which would require a shift in stress placement. Whalley and Hansen (2006) presented a spoken noun phrase to children and asked them to indicate whether they heard “football and socks” or “foot, ball, and socks”. Wood and Terrell (1998) and Clin et al. (2009) asked children to make same-different judgements on pairs of sentences, one of which had been low-pass filtered to remove phonemic content but leave prosodic contours intact. All of these studies made claims about children’s prosodic competence although different aspects of prosody were assessed. Tasks differed in being receptive or expressive, the degree of metalinguistic control required, and whether word, phrase, or discourse prosody was tapped. Additionally, some studies (e.g., Holliman et al., 2010) assess stress, intonation and timing separately, although in natural language these features co-occur. Unlike the early studies of phonological awareness showing that it was largely a unidimensional construct (e.g., Stanovich et al., 1984), no study has comprehensively and systematically analyzed tasks of prosodic competence in the same way.

Prosody in the orthographic system.

The RSF shows that the linguistic system links to the orthographic system, which addresses knowledge of print-sound mapping. This linkage must also include suprasegmental information, with special consideration for multisyllabic words. Some languages mark suprasegmental phonology overtly (e.g., Greek and Spanish diacritics; the pinyin system in Mandarin). For these languages, how suprasegmental phonology is involved in the orthographic system is clear. However, such a relationship is equally present in languages like English, where the location of stress is variable, but there are no formal orthographic markers of word stress.

Instead, certain graphotactic probabilities are associated with word stress placement, located specifically at word endings (Arciuli & Cupples, 2006; Monaghan et al., 2016). For example, despite a general English-language bias for trochaic, or first-syllable stress, 86% of all disyllabic

English words ending in *-uct* have second syllable stress. Another example of how word-level prosody is implicated in the orthographic system relates to the near-obligatory vowel reduction of unstressed syllables in English words. Vowels in unstressed syllables can be spelled with any vowel grapheme, but they are typically reduced to schwa (Bebout, 1985; Weber, 2018). Relatedly, linking suprasegmental phonology to the orthographic system also resolves some inconsistencies in sound-symbol mapping of orthographic rimes. For instance, *-ain* is pronounced /en/ in one-syllable English words with perfect consistency (e.g., *train, pain*). Disyllabic words, however, lose consistency unless word stress is taken into account; *-ain* preserves consistency when it falls in a stressed syllable (e.g., *explain* vs *mountain*).

Recently, Levesque et al. (2021) proposed that morphology also belongs in the orthographic system of the RSF as a source of knowledge around mapping orthographic units to morphological constituents. Derived words that have a phonological or orthographic change in the derivation from the base word are more difficult for children and low-literate adults to read and spell than are derived words where there is no such change (Carlisle, 2000; Jarmulowicz, 2002; To et al., 2016). In some languages, morphological derivation has a predictable impact on word prosody. In English, a large class of derivational suffixes (e.g., *-al, -ity*) are associated with a shift in primary stress from its location in the word's base to the syllable before the suffix (e.g., *major - majority*). These contrast with another class of suffixes (e.g., *-ness, -ful*) which have no effect on word stress (e.g., *beauty – beautiful*). Clin et al. (2009) showed that "phonological change" in derivation was particularly challenging when word stress was involved; in this study, children in grades 3, 5 and 7 were less accurate at forming derived words with phonological changes that involved stress changes (e.g., *atom - atomic*) than words where the shift changed the phonemes only (e.g., *correct - correction*). The items in this study were equated for frequency and morphological family size, and none required orthographic changes between base and derivation. All children found morphological derivations involving stress changes to be more difficult than those that did not, but this difference was most pronounced for children in grade 3, at about 35% correct, than for older children in grades 5 and 7, who performed at about 65% correct. And notably, performance on items with phonemic changes only was as accurate as that on items with no changes.

The stress-shifting effect of this class of derivational suffixes was also observed directly in reading in Wade-Woolley and Heggie (2015). In this study, adults first read a list of nonwords (e.g., *frosure, bistin*), then read a second set of nonwords derived from the first list (e.g., *frosureful, bistinity*). Words with stress-neutral suffixes showed that readers placed stress in the same syllable in both bases and derivations (e.g., *FROsure - FROsureful*) and shifted stress as predicted with stress-shifting suffixes (e.g., *BIStin - bisTINity*) nearly 80% of the time. Similar findings were observed in Greek, in which morphological suffixation is associated with changes in stress placement (Grimani & Protopapas, 2017).

Prosody in the lexicon.

Suprasegmental phonology should also feature in the lexicon, as the phonological representation, including stress assignment, is part of the lexical entry for every word. Evidence that prosody is represented at the lexical level is provided by Ashby and Clifton (2005), who showed that words with two stressed syllables (*preposterous*) took longer to read and had more fixations than matched words with one stressed syllable (*ostentatious*), independent of word frequency. In some cases, word-level prosody is associated with grammatical category. Some English homographs are minimal pairs that differ only in stress placement, such as *record* and *produce*, depending on whether they are a noun or verb. In a corpus study of 3000 English words, Kelly and Bock (1988) demonstrated that 94% of nouns have trochaic stress and 69% of verbs have iambic stress. Experimental evidence such as speeded grammatical classification (Davis & Kelly, 1997) and gating in word identification (Arciuli & Cupples, 2004) has demonstrated that adults are sensitive to this information, performing more quickly or requiring less information to reach a decision when stress placement is consistent with part of speech. By definition, homographs have more than one pronunciation and determining the correct mapping of orthography to phonology in the cases like those we have just described will depend on the syntactic contexts in which the words are found. For example, Kelly and Bock (1988) showed that adults were more likely to pronounce nonwords with trochaic stress when they appeared as nouns in a sentence, and to assign iambic stress when they appeared as verbs.

Prosody in comprehension processes.

The RSF shows syntax and semantics in the linguistic system as sources of knowledge for comprehension processes. In oral language, syntax and discourse information are often associated with prosodic elements such as pausing and pitch change. Research interest in prosodic reading (‘reading with expression’) has emerged regarding how this relates to reading comprehension and fluency (Dowhower, 1991; Kim et al., 2021; Kuhn & Stahl, 2003; Kuhn et al., 2010). Prosodic reading is assessed by measurement of acoustic features, such as intra- and intersentential pause frequency and duration, or changes in fundamental frequency, or by subjective ratings of pacing, expression, and smoothness (e.g., Arcand et al., 2014; Paige et al., 2014; Rasinski et al., 2017; Schwanenflugel et al., 2004). In a meta-analysis of 35 studies, Wolters et al. (2020) found an overall relation of r = .51 between reading prosody and comprehension, although this differed as a function of how reading prosody was measured;

adult-like intonation contour (e.g., Miller & Schwanenflugel, 2008; Mokhtari & Thompson, 2006) showed a stronger relation to comprehension than did reading prosody measured by a rating scale. Despite this significant relation, the direction of causation between prosodic reading and reading comprehension remains unresolved (Wolters et al., 2020). But if we see prosodic competence as an element represented across the RSF in the way we have proposed, the ways in which prosodic competence could drive growth in both expressive reading and reading comprehension become apparent, at least theoretically.

In contrast to the prosodic reading literature, only limited research has examined how prosodic competence is related to reading comprehension. Pauses and pitch changes while storytelling (Groen, et al., 2019; Veenendaal et al., 2015), repeating a modeled sentence (Breen et al., 2016) and prosodic chunking to establish syntactic phrasing (Lochrin et al., 2015) have been shown to predict reading comprehension in children and adults. Furthermore, there are other prosodic indicators in speech (see Carlson, 2009), but their contribution to reading comprehension remains largely unexamined. Lengthening a syllable before the edge of a syntactic boundary is one such feature. For example, the word *kids* is longer in (a) *the nice kids plant the garden*, where it ends a noun phrase, than in (b) *the nice kids' plant fell over*, where it is internal to the noun phrase. Children as young as 4.5 years are able to complete grammatically congruent sentences when they hear fragments consisting of the first three words of (a) or (b) above (de Carvalho, 2016). In addition to marking syntactic boundaries, prosody can signal phrase attachment; in *Shaunda wrote to the lawyer from Manitoba*, a prosodic boundary can bias a listener to attach the prepositional phrase *from Manitoba* to either *Shaunda* or to *the lawyer* (Schafer, 1997; Snedeker & Trueswell, 2003). Prosody establishes linguistic focus by making prominent (by pitch accents) the words that link to the previous discourse, either by being contrastive to or new in relation to what has come before. Eye tracking studies have shown that adult listeners are sensitive to the prosody-signaled information structure; when following a series of instructions, anticipatory looks to a new, unmentioned item are increased when contrastive accents are perceived (e.g., *Put the blue ball on the tree; now put the RED ball…* Ito & Speer, 2008) or initial syllables of words (Dahan et al., 2002). Experimental work has shown that pitch accents improve listener comprehension of spoken sentences (e.g., Birch & Clifton, 2002; Cutler & Foss, 1977), but these effects have not yet been investigated as a source of individual differences in reading development.

Even less work has been devoted to the role of prosody in the development of silent reading. A silent prosodic representation of a text ('inner voice') is known as "implicit prosody" (Fodor, 2002). Measuring an individual's implicit prosodic representation of a text is challenging. However, researchers have used online methods such as eye-tracking and event-related potentials (ERPs) to demonstrate the presence of implicit prosodic representations, and evidence that such representations facilitate comprehension (see Breen, 2015 for review). In a series of ERP studies, Steinhauer (2003) found that commas placed in written text during adults' silent reading elicit a similar online brain response to phrase boundaries placed in oral speech. Similarly, in an eye-tracking study Wonnacott et al. (2016) found that children as young as 8 and 10 years were able to benefit from the prosody conferred by commas, which block ambiguity of garden path sentences such as *While Jim was eating[,] the biscuits baked in the oven*. Thus, punctuation appears to act as a visual analog to prosody and likely aids reading comprehension in the same way.

We have demonstrated how prosody may be accommodated in the RSF as a source of linguistic knowledge involved in word reading and reading comprehension, but what does the evidence say about prosody in relation to reading development? Does prosodic competence contribute to reading development in different ways at different time points? As prosodic competence is evident in pre-school children, does it contribute to reading from the outset?

Mapping Developmental Evidence of Prosodic Competence and Reading Outcomes

There have been a small number of longitudinal studies that have examined children's prosodic competence and its contribution to either reading outcomes, or to later developing skills known to underpin reading performance. We review their results to map some of the observed pathways through which prosodic competence contributes to the development of reading. We then use this as a framework for situating the results of more experimental work that has also sought to examine the contribution of prosody to reading, in order to propose likely pathways from prosodic competence to reading outcomes.

One of the first longitudinal studies examining prosody and reading was conducted by Holliman et al. (2010). A sample of school age children completed assessments of prosodic competence, rhyme awareness, phoneme deletion, and vocabulary at ages 5 - 8, and measures of word reading, reading comprehension and reading fluency one year later. For prosodic competence, children heard a list of two-syllable words with the primary stress reversed (e.g., builDER). They were asked to identify the correct word by manipulating the stress (e.g., BUILder) to the correct position and matching it to the target item among four pictures (see Mispronunciations Task in Table 1). Time 1 (5-8 yrs) prosodic competence was significantly correlated with all the Time 2 (6-9 yrs) reading measures, and could predict variance in word reading and phrasing when reading aloud after controlling for age, vocabulary, and phonological awareness. Although the age range of the sample was broad, this study does demonstrate a relatively robust longitudinal association between performance on a simple measure of prosodic competence and later word reading, which is not entirely accounted for by developmental, lexical or phonological factors.

In a more complex longitudinal design, Calet et al. (2015) assessed the reading ability and prosodic competence of Spanish children at the end of Kindergarten, using measures of lexical and metrical stress sensitivity, and assessed them again at the beginning and end of Grade 1 and Grade 2. The lexical stress sensitivity measure involved hearing a real word and matching it with the picture of the set of mountains that represented the correct stress pattern similar to the Stress Identification task described in Table 1). The metrical stress sensitivity measure was a Compound Nouns task described in Table 1. Path analysis (controlling for non-verbal IQ, vocabulary, and phonological awareness) revealed that lexical stress sensitivity at the beginning of Grade 1 significantly predicted reading at the end of Grade 1. In contrast, metrical stress sensitivity at the end of Grade 1 and beginning of Grade 2 could predict reading at the beginning of Grade 2 and end of Grade 2, respectively. These patterns suggest that word and phrase level prosodic competence may contribute to the development of reading ability at different points in development.

Later work considered the relative contributions of prosodic competence and morphological awareness to word reading and reading comprehension over a two year period (Deacon et al., 2018). Prosodic competence, phonological awareness, morphological awareness, and vocabulary were assessed when children were 5-7 years, and the children completed measures of word reading, reading accuracy, and reading comprehension two years later. A composite measure of prosodic competence was used in this study including lexical stress using the low-pass filter matching task described in Table 1, intonation, and timing task. Longitudinal associations were observed between prosodic competence and all three outcome measures when the children were

7-9 years old. However, once phonological awareness, vocabulary, and developmental effects were controlled, these relationships disappeared, whereas the relationships with morphological awareness survived. However, it should also be noted that concurrent relationships were reported between prosodic competence, vocabulary, morphological awareness, and phonological awareness. Consequently, the authors suggest that the contribution of prosodic competence to word reading and comprehension over this longer time period is likely to be indirect, via factors like morphology and phonological awareness.

Prosodic competence has also been examined longitudinally in a sample of children with dyslexia. Syllable stress perception (see DEEdee matching task in Table 1) was examined in a group of 9-year-old children with developmental dyslexia alongside rhyme sensitivity and basic auditory processing (Goswami et al., 2013). These children were then reassessed on their reading outcomes, auditory processing, segmental phonological awareness, and syllable stress perception four years later when the children were age 13. At age 9, the children with developmental dyslexia showed a specific deficit in syllable stress perception relative to both chronological age and reading age matched control groups. This contrasts with their performance on the auditory processing and segmental phonological assessments, where they only demonstrated a deficit relative to their same age peers. So for children with reading difficulties, there is quasi-experimental evidence of a specific prosodic competence deficit in children with reading difficulties, which is observable after around four years of formal reading instruction, and is more pronounced than phonological or basic auditory processing difficulties. Four years later, the children with dyslexia were observed to have worse syllable stress perception then their chronological age matched controls, and their general auditory processing at age 9 was able to predict significant variance in syllable stress perception at age 13, even after controlling for syllable stress perception at 9 years. These results are interpreted as support for the idea that prosodic competence is developmentally underpinned by children's basic auditory processing. However, when we look at the longitudinal relationships between the various measures assessed at Time 1 (9 years) and Time 2 word reading (13 years), we also find that the prosodic and segmental phonological measures taken at Time 1 together explain about a third of the variance in word reading at Time 2, and offer a stronger predictive relationship with reading than that observed for the basic auditory processing measures. What this study is unable to demonstrate is whether basic auditory skills assessed prior to the development of reading ability might still account for individual differences in the development of prosodic competence. So although the idea that basic auditory skills can account for growth in the development of suprasegmental phonology makes sense, and concurrent relationships between the two skills have been observed in this and other studies, this important foundation piece of the developmental account has yet to be demonstrated empirically. We do, however, note that there is separate evidence of a longitudinal association between basic auditory processing and growth in rhyme awareness between the ages of 4 and 5 years (Corriveau et al., 2010).

Most recently, Critten et al. (2021) reported the results of a one-year longitudinal study, which sought to examine the contribution of prosodic competence to reading and spelling development. The design of this study improved on previous research in a number of ways. Firstly, the children were assessed to be pre-readers at Time 1 (4-5 yrs) , thereby enabling the examination of prosodic competence before the children's reading ability had started to emerge. This group of children were therefore younger than previous samples, and represented a year group cohort, rather than a wider age range. Children's prosodic competence, vocabulary, phonological awareness, and morphological awareness were assessed when the children were pre-readers and their word reading and spelling was assessed one year later. A global measure of prosodic competence was used including a compound noun task (see Table 1), stress identification task, intonation, and timing. It was significantly associated with both written language skills. A path analysis showed significant concurrent associations between prosodic competence, and rhyme, vocabulary, and morphology when children were 4-5 years; vocabulary and rhyme awareness contributed to phoneme awareness, which in turn explained significant variance in reading and spelling the following year.

We argue, based on the above evidence, that prosodic competence is best seen as making an indirect contribution to reading and reading comprehension. However, we observe that the longitudinal studies of prosodic competence often fail to demonstrate directional associations between prosodic competence, phonemic awareness and morphological awareness, because these tend to be assessed at the same (baseline) timepoint. Goswami et al. (2013) did assess the relationship between prosodic competence (detection of syllable stress) at age 9 and phoneme deletion at age 13, and was unable to find evidence of an association after age, IQ and earlier rhyme awareness were controlled, suggesting that it was unable to explain growth in phonological awareness over time. However, we should be somewhat cautious as the syllable stress task used at Time 1 was observed to have somewhat low reliability and also assessed just one specific aspect of prosodic competence.

As a result, we need to examine other types of studies for further evidence linking prosodic competence to reading development. Studies that fall into this category are experimental studies that compare children who have received prosodic competence training to nontrained controls on their prosodic competence and reading ability. Quasi-experimental studies, while lacking experimental manipulation and random assignment, are still informative. These studies compare children with impaired prosodic competence to typically developing controls on their reading abilities. A third type of quasi-experimental study that would add explanatory power would include those that have compared children with reading difficulties to controls on their prosodic competence, and demonstrated that children with reading difficulties show deficits relative to at least their chronological age matched peers (e.g., Wood & Terrell, 1998). Studies in this last group suggest that prosodic competence may be linked to reading outcomes, but as prosodic competence was not the manipulated factor within these designs they offer a weaker form of evidence. However, we should highlight the results of a principal component analysis of a wide range of spoken and written language skills that were assessed across a sample of children including those SLI only, those with dyslexia only, those with both SLI and dyslexia, and children who had no impairments (Ramus et al., 2012). This analysis revealed five factors that together explained 69% of the variance in language skills across the sample. This included non-phonological language skills, phonological skills, phonological representations, prosody perception, and melodic skills. These last two factors together explained 17.5% of the variance, and highlight how prosodic skills sit apart from other forms of phonological and non-phonological language abilities.

There is little research that has directly compared children with impaired prosodic competence to controls on reading or reading-related skills. One place where we can find such comparisons is within the literature on children with specific language impairment (SLI) (now termed developmental language disorder - DLD). SLI/DLD refers to a heterogeneous group of children with good non-verbal reasoning abilities but impaired oral language skills and phonological memory (e.g., Conti-Ramsden et al., 2001; Gathercole & Baddeley, 1990). These children also experience difficulties with spelling (Larkin & Snowling, 2008), decoding, and reading comprehension (e.g., Nation & Norbury, 2005).

Recently, empirical evidence has shown that children with SLI/DLD demonstrate impaired prosodic competence (e.g., Fisher et al., 2007; Ladányi et al., 2020; Marshall et al., 2009; Richards & Goswami, 2019; van der Meulen, Janssen & den Os, 1997). Moreover, it has been argued that age-related deficits in the ability to spot metrical and syntactic disruptions in children's texts are best understood as the result of impaired acoustic processing of speech rhythm in DLD, an account which has been proposed to explain the characteristic difficulties in language processing associated with the condition (Richards & Goswami, 2019). In fact, rhythm-based processing difficulties are so characteristic of developmental speech and language disorders that Ladányi et al. (2020) recently proposed the Atypical Rhythm Risk Hypothesis, which argues that children with atypical rhythmic processing abilities are at increased risk of developing speech and language disorders.

Given the characteristic nature of prosodic processing difficulties observed in SLI/DLD populations, we should find that these groups differ from carefully matched controls on measures of reading and reading-related skills. Williams et al. (2013) report that their SLI group was significantly worse than both chronological age and spelling age-matched controls on standardised measures of spelling, reading, vocabulary, and grammar. Similarly, Critten et al. (2014) reported that the children with SLI were significantly worse than both chronological age and language and spelling age controls on word reading, spelling ability, phonological awareness, and inflectional morphological awareness.

It seems then that explanations of SLI/DLD increasingly centre on proposals that oral language difficulties are rooted in systems supporting the acoustic processing of speech rhythm. Moreover, there is evidence that children with SLI /DLD present with difficulties in vocabulary, morphology, phonology, and literacy. What is missing from this account is a single longitudinal study that examines the prosodic competence of children with and without DLD alongside reading skills, such that we can show a developmental association between prosodic deficits and reading outcomes. However, the evidence remains that children with SLI/DLD are characterised by compromised prosodic competence, and in line with our hypotheses we find that this group experience specific difficulties in written language skills.

Perhaps the most compelling evidence of a causal relationship might come from experimental studies where children have been randomly allocated to an intervention group which then receives training in prosodic competence. To date there has been one study that has demonstrated a training effect of prosody on reading outcomes. Harrison et al. (2018) developed a 10-week programme of short activities to support 4- to 5-year-old children's explicit understanding of stress (children practiced identifying whether the pronunciation of a pictured object was correct, e.g., SOfa, or incorrect, e.g., soFA), intonation (e.g., children practiced identifying whether a spoken phrase was asking or telling them something), and timing (children practiced identifying whether they heard one word, e.g., football, or 2 if they heard two words, e.g., foot, ball) for a total of 150 training minutes. A sample of typically-developing children were randomly allocated to either the prosody training group, a phonological awareness training group, or a neutral training (mathematics-based) control group. All children were pre, post and delay post-tested on measures of prosodic competence, phonological awareness, reading and vocabulary. The children in the prosodic training group improved in their prosodic competence relative to both comparison groups, and outperformed the neutral control group on the word reading subtest of the British Ability Scales at both immediate and delayed post-test (Cohen's d = .75 and .72, respectively). Moreover, the prosody training group performed at the same level as the phonological awareness training group. The authors speculate that the training may have influenced reading through enhanced metalinguistic awareness of suprasegmental phonological features such as pitch changes, pause duration and amplitude. One cannot know from this study if the training effect was driven by one of the activities more than another, or if each activity contributed independently. It was assumed that enhanced sensitivity to speech rhythm may facilitate segmental phonological awareness, because peaks in amplitude (which are perceived as 'beats' or stressed syllables) also correspond to vowel location and therefore cue onset-rime boundaries. However, it may also be the case that prosodic competence enhances the encoding of words with word meanings (as noted earlier), and this in turn benefits word recognition. However, experimental work is needed to directly examine the validity of both explanations.

An Evidence-Based Model

When we collate the evidence, drawing only from longitudinal and experimental work (i.e., excluding cross-sectional, correlational studies) that has examined the linkages between prosodic competence and reading outcomes as outlined above, we can summarise it in the model presented in Figure 2.

Insert Figure 2 about here

There is evidence to support the idea that prosodic competence is underpinned by basic auditory processing. Prosodic competence itself is linked concurrently and experimentally to individual differences in phonological awareness and morphological awareness. These two skills are linked longitudinally to word reading and reading comprehension. There is some evidence of a direct link between prosodic competence and word reading, but it seems likely that these influences are mediated by shared variance in morphological awareness, which was not examined by the supporting studies in question, and so requires further investigation.

Testing the Model with a Non-Alphabetic Language

The model in Figure 2 provides a basis for understanding how prosodic competence might be involved in literacy development in non-alphabetic languages. Research with Chinese samples has highlighted the contribution of tone awareness to reading development at different developmental time points (e.g., Chung et al., 2017; Chung & Bidelman, 2021; McBride-Chang et al., 2008; Yin et al., 2011). Many of the concurrent associations outlined in the evidence-based model align with studies conducted with Chinese monolinguals. For example, Chinese children with dyslexia perform worse on measures of prosodic competence (e.g., tone discrimination and tone production) than controls (Li & Ho, 2011; Wang et al., 2017) suggesting a deficit in auditory processing similar to that observed above. Given the strong connections between prosodic competence and semantics in word learning, we expect that lexical tone awareness will also have a direct and indirect influence on a range of Chinese reading outcomes, mainly through morphological awareness and, to a lesser degree, phonological awareness. For example, Zhang and McBride-Chang (2014) examined the relationship between auditory sensitivity, speech perception, linguistic measures and Chinese word reading among second and third graders in Hong Kong. They found concurrent associations between basic auditory processing and speech perception at the segmental and suprasegmental level (tone awareness measures), direct relationships between tone awareness and phonological awareness, naming speed, verbal short-term memory, and morphological awareness, and an indirect effect of tone awareness on Chinese word reading via morphological awareness and rapid automatized naming. It is interesting to note that prosodic competence in Chinese is important for a range of Chinese reading outcomes from character reading to reading comprehension. Chung and Bidelman (2021) report unique contributions of tone perception (9%) on character recognition (26% total variance explained) when entered before phonological awareness, and significant contributions of tone perception (20%) to reading comprehension (51% total variance explained) above and beyond phonological awareness. However, much of the data linking Chinese prosodic competence and reading is based on concurrent associations. Longitudinal studies are needed to dissociate the role of prosodic competence across stages of learning to read among Chinese monolinguals, and further research is needed to examine the potential of training prosodic competence (e.g., Wang, 2017; Zhou et al., 2012) as a method of enhancing reading outcomes.

Conclusions and Future Directions

We argue that prosodic competence is implicated in all aspects of the reading process. We agree with Hirotani et al. (2006, p. 439-440) that we should not be surprised that reading is parasitic on the same mechanisms that underpin comprehension of speech: "What would be shocking is if the rich structuring provided by the intonational system could simply be set aside during reading." In this paper we have shown how prosody can be incorporated into the Reading Systems Framework. As a key aspect of the phonological component of the linguistic system, prosody is integrated with syntax, morphology, and segmental phonology, and is implicated in both word reading and reading comprehension. We have presented empirical evidence to support these relationships. We believe, however, that there is scope for further research into prosody and reading development. Below, we identify several important directions for future research needed to better understand the role of prosodic competence in reading.

To date, the clear majority of studies in this area have been correlational in design. More experimental studies are needed to test the potential explanatory relationships that we have outlined here. The potential of prosody-based training studies remains largely unexplored. Experimental studies are needed to unpick mechanisms of causation, but additional studies are needed to include more comprehensive assessment of prosodic competence, reading and sub-lexical skills. Longitudinal studies that test how prosody develops in children from pre-reading through to skilled reading are also required. While still correlational in nature, studies that assess the same constructs across multiple time points would rule out potential alternative explanations for observed relationships (e.g., reading experience improves prosodic understanding; Arciuli et al., 2010; Kelly et al., 1998) and should enable us to understand direction of causation in a way that cross-sectional correlational studies do not. Unfortunately, existing longitudinal studies examining prosody often fail to demonstrate directional associations between prosodic competence, phonological awareness, and morphological awareness, because these skills tend to be assessed only once within the design, at the different time points, rather than at several points in development (e.g. prosody is only assessed at Time 1, and reading outcomes are assessed at Time 2, rather than both being assessed at both time points using developmentally appropriate measures of these constructs). Appropriately designed longitudinal studies are therefore important to help us understand the changing contribution of prosodic competence over the course of reading development, as they enable us to understand the direction of association, as well as providing conservative accounts of contribution to reading development where autoregressors can be factored into analyses.

It would be useful to address the range of tasks used to determine prosodic competence. The diversity of measures used in the literature may contribute to equivocal research findings. It is not yet known whether these tasks are redundant with each other as they relate to reading development. It would be useful to determine whether word, phrase, and discourse prosody relate equally to word reading and reading comprehension. We also need measures and studies which examine the contribution of prosodic competence across languages to help us integrate our understanding of prosody in relation to different orthographies and language-specific suprasegmental features.

We have discussed prosodic competence in Chinese speakers in this review, but the field would also benefit from additional cross-linguistic comparative studies to assess, for example, how prosodic competence contributes to reading in the context of languages that mark prosodic information overtly (e.g., Spanish, Greek) compared to languages that do not (e.g., English), or how prosodic competence contribute to reading and spelling in languages with vowel reduction in unstressed syllables (e.g., English) compared to languages without (e.g., Spanish). Finally, while the extant literature is replete with studies of children with reading or language difficulties, more research is urgently needed to understand the role that prosodic competence plays in the reading development of typically developing children. Not only would such a foundation provide critical information about different aspects of prosody and reading as children develop, it would afford greater clarity in the interpretation of the studies of prosody in the reading skills of special populations. And perhaps most importantly, such work would help identify which aspects of prosody are most amenable to and efficacious for possible interventions.

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Table 1.

Measures of Prosodic Competence Commonly Used to Investigate its Relationship with Reading.

Prosody measure	**Response Type**	**Description/ Example**	**Example Publications** ***[Language other than English]*** *study referenced in current paper
Compound Noun Task	Receptive	Participants hear *[chocolate] [cake] and [honey]* or *[chocolate cake] and [honey]* and they must identify whether they hear three items or two items.	Calet et al. (2015)* *[Spanish]*; Goodman et al. (2010)*; Harrison et al. (2018)*; Nash & Arciuli (2014)*
DEEdee Matching task	Receptive	Participants hear the target word (e.g., "Tooth Fairy") and are asked to match it to one of two phrases with the same stress pattern ("DEEdeedee") or a different stress pattern ("deeDEEdee").	Chung et al. (2017)* *[Chinese];* Clin et al. (2009)*; Enderby et al. (2021)*; Goswami et al. (2010)*; Goswami et al. (2013)*; Whalley & Hansen (2006)*
Low-pass Filter Matching Task	Receptive	Participants are asked to match a spoken phrase or sentence to speech that has been low-pass filtered. A low-pass filter removes all acoustic cues above a certain frequency—keeping prosodic contours but removing phonemic information.	Clin et al. (2009)*; Holliman et al. (2014)*; Deacon et al. (2018)*; Fisher et al. (2007)*
Mispronunciations Task	Receptive	Participant hears two-syllable word objects pronounced with incorrect stress placements and select the picture of the word the speaker was trying to say (e.g. The participant hears paRROT and chooses from a picture of a panda, parrot, paper, and kayak).	Goodman et al. (2010)*; Harrison et al. (2018)*; Nash & Arciuli (2014)*; Wood (2006)*

Profiling Elements of Prosody in Speech Communication (PEPS-C)	Receptive/ Expressive	Participants complete a battery of 14 separate tasks, including measurements of sensitivity to turn end (i.e., was the speaker asking a question or making a statement), affect (i.e., was the speaker happy or unhappy), lexical stress (see Stress Identification task), phrase stress (see Compound Noun task). Each task has a receptive and expressive version.	Groen et al. (2019) *[Dutch]*; Marshall et al. (2009)*; Lochrin et al. (2015)*
Prosodic Imitation Task	Expressive	Participants are instructed to listen to a sentence, and then repeat the sentence aloud themselves while imitating the prosodic structure.	van der Meulen et al. (1997)*; Breen et al. (2016)*
Stress Identification	Receptive	Participants listen to disyllabic/multisyllabic words or pseudowords, and clap or identify where the main beat or primary stressed syllable is within the word/pseudoword.	Calet et al. (2015)* *[Spanish]*; Chan & Wade-Woolley (2018)*; Defior et al. (2012)* *[Spanish]*; Gutiérrez-Palma et al. (2016)* *[Spanish]*; Kim & Petscher (2016)*
Tone Detection	Receptive	Participants see two pictures that only differ in lexical tone. They are instructed to match the target tone that they hear to the correct picture.	Ciocca & Lui (2003) *[Chinese]*; Zhang et al. (2014)* *[Chinese]*
Tone Discrimination	Receptive	Participants are presented with four pictures and hear four monosyllables that correspond to each picture. Three of the monosyllables have the same tone and participants select which one has a different tone from the rest.	Tong & McBride-Chang (2010)* *[Chinese]*; Tong et al. (2018) *[Chinese]*

Tone Perception/Tone Judgment	Receptive	Participants hear three one-syllable words. The first syllable is the target, and the second and third syllable either contain the same tone or a different tone from the target. They select which syllable has the same tone as the target.	Li & Ho (2011)* *[Chinese]*; Liu & Hu (2010) as cited in Chung et al. (2017) *[Chinese]*; Yin et al. (2011)* *[Chinese]*

Note. These tasks may be referred to by other names in various publications. Receptive Response = Participants are evaluated on their ability to identify, discriminate, match, or judge the difference between stimuli presented aurally. Expressive Response = Participants are evaluated on their ability to produce or imitate the prosodic qualities of words, phrases, sentences and/or longer texts.

Figure 1

Prosody Incorporated in the Reading Systems Framework (adapted from Perfetti, Landi & Oakhill, 2005; Perfetti & Stafura, 2014)

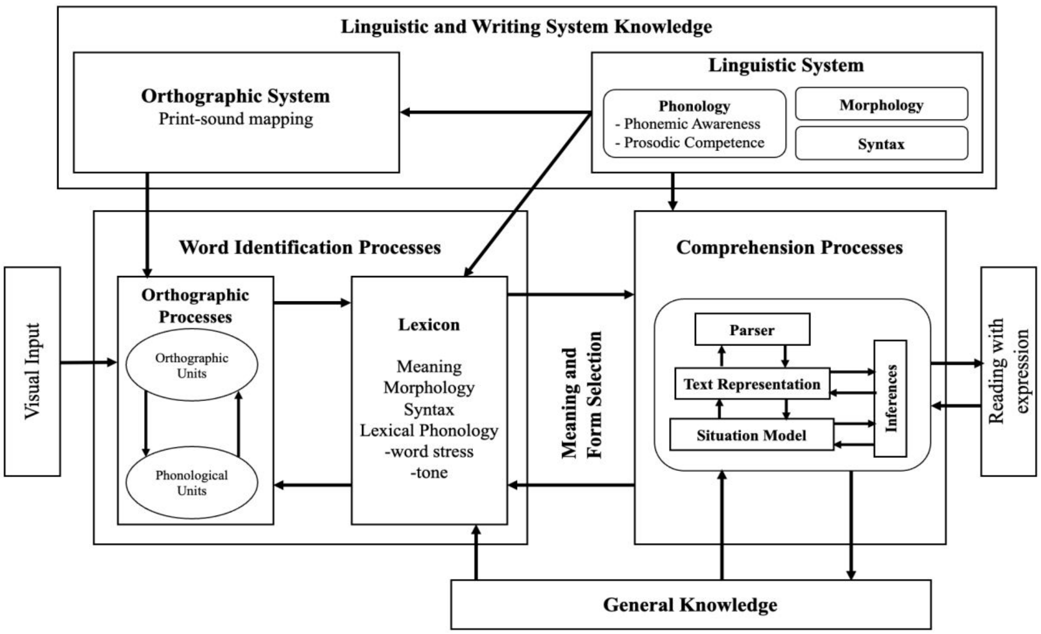

Figure 2

Diagram Mapping Relationships Between Prosodic Competence and Reading-Related Measures Demonstrated in the Context of Longitudinal and (Quasi-) Experimental Studies of Non-Tonal Languages