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Original citation & hyperlink:
Holliman, A 2016, Suprasegmental phonology and early reading development: Examining the relative contribution of sensitivity to stress, intonation and timing. in J Thomson & L Jarmulowicz (eds), *Linguistic Rhythm and Literacy.* Trends in Language Acquisition Research , vol. 17, John Benjamins Publishing Company, Amsterdam, Netherlands, pp. 25-50
https://dx.doi.org/10.1075/tilar.17.02hol
https://www.benjamins.com/catalog/tilar.17

DOI 10.1075/tilar.17.02hol
ISBN 9789027244079
ESBN 9789027267559

Publisher: John Benjamins Publishing Company

Suprasegmental phonology and early reading development: Examining the relative contribution of sensitivity to stress, intonation, and timing [R1].

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Abstract

This chapter aims to disentangle the complex relationship between the different components of suprasegmental phonology and early reading development. Specifically, it considers the possibility that suprasegmental phonology may not be a unitary construct and explores whether the different suprasegmental components of stress or loudness, pitch or intonation, and duration or timing (Kuhn & Stahl, 2003, p.5) are related to reading development in different ways. It draws primarily upon published research evidence and theory along with some pertinent unpublished data from two recent exploratory studies, which developed and employed a new, multi-component measure of suprasegmental phonological sensitivity. Conclusions are made regarding the need to consider disentangling suprasegmental phonology not only theoretically but practically, in order to develop a more sophisticated understanding of its role in early reading development.

Keywords: suprasegmentals; prosody; stress; intonation; timing.

The importance of suprasegmental phonology – the 'neglected' phonology

One of the most consistent and widely accepted findings over the past few decades is that reading difficulties arise from underlying deficits in phonological processing (Bus & van IJzendoorn, 1999; Cain, 2010; Snowling, 2000, although see Castles and Coltheart, 2004, who argued that a 'direct causal' association had not been demonstrated at the time of publishing their article). Poor readers have often been found to have accompanying phonological processing deficits (e.g., Brady & Shankweiler, 1991; Ramus et al., 2003; Vellutino & Fletcher, 2005) and precocious readers have often been found to display superior phonological processing skills (e.g., Stainthorp & Hughes, 1998, 2004). Such findings have lead some (e.g., Stanovich, 1988) to argue in accordance with the 'phonological core-variable difference model' that poor readers differ from typically-developing readers on all skills which tap into the phonological core deficit.

While an established literature has shown that phonological deficits may underpin reading difficulties, it is important to note that the term 'phonological' here has often been used exclusively to refer to the processing of 'segmental' phonological information; that is, knowledge that the word 'mud' for example can be broken down into separable sound segments such as 'm-u-d' (by phonemes) or 'm-ud' (by onset-rime). Such segmental abilities are highly correlated and strongly linked to early reading development (see Anthony & Lonigan, 2004). However, over the past 15 years in particular, a growing literature has begun to emerge which focuses on another kind of phonology that has received far less attention – that of 'suprasegmental phonology'.

Recent evidence suggests that suprasegmental phonology may not only support the development of segmental phonological skills (see Goswami et al., 2002; Kuhl, 2004; Wood, Wade-Woolley, & Holliman, 2009, and also later sections of this chapter), but may also support a range of literacy skills independently of this association (see Clin, Wade-Woolley, & Heggie, 2009; Goswami, Gerson, & Astruc, 2009; Holliman, Wood, & Sheehy, 2008, 2010a, 2010b, 2012; McBride-Chang, Lam et al., 2008; Shu, Peng, & McBride-Chang, 2008; Whalley & Hansen, 2006; Wood, 2006a; Wood, 2006b; Wood et al., 2009). Such findings imply that the definition of phonological skills relevant to reading development may need to be broadened to incorporate suprasegmental phonology – an argument no doubt made by other authors in this volume.

So, what exactly do we mean by 'suprasegmental phonology'? The editors of this volume should be commended for their attempts to develop a theoretical framework and define some of the commonly used yet often underspecified terms in the linguistics and reading development field; indeed, terms such as 'suprasegmentals', 'prosody', 'intonation', and 'rhythm' have been used interchangeably (even in my own papers). It is worth pausing for a moment to reflect on the term chosen for the title of this chapter – 'suprasegmental phonology' – which, according to the editors, is the broadest of these terms and refers to the acoustic, physical properties of the speech stream, including intensity, fundamental frequency, and duration of the signal (Shriberg & Kent, 2003) that are perceived as variations in loudness, pitch, and length respectively (or perhaps stress, intonation, and timing). The term 'prosody', defined by the editors as encompassing a broad range of phenomena including phrasing, pausing/tempo, rate, loudness, and stress (Shriberg, 1993), was another strong candidate for the title of this chapter, but the former was selected because it seems to foster a selection of the widest literature.

Interestingly, in the same way that the term 'phonology' has been discussed almost exclusively in terms of segmental phonology, the term 'suprasegmental phonology' (or 'prosody') has also been used too generally in the literature often when only a single component of suprasegmental phonology (i.e., stress, intonation, or timing) has been studied; or at least, when multiple components have been studied, but under the label of a single component (e.g., stress) in a non-delineated fashion. Such generalisation has prevented any kind of examination of the relationship between the different suprasegmental components and their relative (and comparative) contribution to early reading development. Research of this kind has importance given that the sparse literature available (which has assessed more than one delineated component of suprasegmental phonology in single study) has found that the different components may be related to reading development in different ways. For example, Miller and Schwanenflugel (2006) and Ravid and Mashraki (2007) have reported stronger links between intonation and comprehension than between pausing (or timing) and comprehension. Indeed, the need to disentangle suprasegmental phonology has been acknowledged by researchers in the field; for instance, Miller and Schwanenflugel (2008, p.339) speculate "…it is possible that different aspects of prosody [suprasegmental phonology] may be linked to different aspects of the reading process".

Holliman et al. (2010a, p.364) also argued that "…further research should consider the ways in which different aspects of prosody [suprasegmental phonology] are related to the reading process". In an attempt to respond to such calls, the relative contribution of the different components of suprasegmental phonology (stress, intonation, and timing) to early reading development will now be considered.

Exploring the role of the different components of suprasegmental phonology

A word of caution…

Prior to reading the following sections on the relative contribution of the different suprasegmental components of stress, intonation, and timing to early reading development, it is important to note that the 'seemingly' different components are rarely conceived as 'entirely' distinct from one and other either in terms of definition or measurement. This is evident in the definition of strong, stressed syllables (see the next paragraph) which includes reference to the terms 'intonation' and 'duration' (timing). This is also evident in many published assessments of suprasegmental phonology which simultaneously manipulate multiple components, but in a non-delineated fashion, which of course makes it difficult to ascertain the relative contribution of each. Therefore, in reading the literature that follows, it is important to appreciate that while the definitions, measurements employed, associated findings, and theoretical explanations, may focus predominantly on a single aspect of suprasegmental phonology (e.g., stress), they may (and often do) span to some degree across other suprasegmental components. For this reason, caution is offered with respect to treating these suprasegmental components as 'entirely' distinct at this stage.

The contribution of 'stress' to early reading development

English is a stress-timed language where speech rhythm is metrical; that is, characterized by strong and weak syllables (Wood & Terrell, 1998). A strong (stressed) syllable contains a 'full' vowel sound (e.g. /u:/ in two) and is characterized as louder, articulated more forcefully, higher in pitch, and longer in duration (Graddol, Cheshire, & Swann, 1987). A weak syllable carries less intensity and often contains a reduced or abbreviated vowel, such as a 'schwa' /ə/, e.g. the 'weak-strong' word 'today' is often pronounced 't'day' (Wood & Terrell, 1998). In the literature, distinctions have been made between 'metrical stress'; that is, the pattern of strong and weak syllables across an entire utterance e.g. at the phrase/sentence level and 'lexical stress', which occurs at the level of the word, in terms of how each might impact upon early reading skills (see Clin et al., 2009; Goodman, Libenson, & Wade-Woolley, 2010). Such distinctions are discussed in other chapters in this volume (see Wade-Woolley & Heggie, this volume); but this chapter will focus on 'stress sensitivity' more generally. So, how might stress sensitivity contribute to the development of early reading skills?

At present, there are three candidate mechanisms that might connect stress sensitivity and early reading – vocabulary growth, phonological awareness, and morphological awareness.

Regarding vocabulary, one of the challenges for young children learning a language is how to segment the speech stream into separate lexical items; this is less clearly specified than in written language where words are clearly separated by spaces. Cutler and Carter (1987) showed that 85% of lexical words in English begin with a strong syllable and this inspired Cutler and Norris (1988) to put forward a model of speech perception (the Metrical Segmentation Strategy) which argues that at every strong syllable in speech a lexical access attempt (look-up process) occurs, which would be a reasonable predictor of word boundaries. Therefore, it seems plausible that sensitivity to stress in young children might facilitate spoken word recognition, which will ultimately help written word recognition and comprehension.

Stress sensitivity is also an important component of phonological awareness. Wood (2006a, p.271) argued that sensitivity to speech rhythm (and stress in particular) may direct our attention towards phonological features and subsequently enhance phonological awareness. Indeed, phonemes and phoneme boundaries appear to be easier to perceive in stressed rather than unstressed syllables (see Chiat, 1983; Goswami et al, 2002; also see Goswami, this volume) and sensitivity to stress appears to facilitate phonological awareness, even after controlling for other skills such as vocabulary (e.g., Holliman et al., 2008; Wood, 2006b). Phonological awareness, in turn, has been extensively linked to early reading development.

Another skill that has been linked to reading development independently of its association with phonological awareness (Deacon & Kirby, 2004), is morphological awareness (see Berninger, Abbott, Nagy, & Carlisle, 2010), which is concerned with root words, affixes, and suffixes (Jarmulowicz, Hay, Taran, & Ethington, 2008) and represents the smallest units of meaning within a word. Stress can differentiate compound nouns, which are more likely to receive first syllable stress (e.g., 'BLACKbird', 'LIGHThouse', 'HIGHchair') from noun phrases, which are more likely to received final syllable stress (e.g., 'black BIRD', 'light HOUSE', 'high CHAIR') (see Kitzen, 2001; Whalley & Hansen, 2006). Equally, the location of stress in a multisyllabic word is often dependent on the morphological structure of the word (see Carlisle, 1988, 2000); for example, words ending in 'ity' or 'tion' tend to result in a stress placement shift so 'SIMple' becomes 'simPLICity' whereas other suffixes such as 'ness' do not result in a stress placement shift. Growing research (Clin et al., 2009; see also Jarmulowicz, this volume) suggests that children with reading difficulties may be less sensitive to stress and thus less aware of morphological rules when decoding multisyllabic words.

In summary, this section has shown that sensitivity to stress may support the development of vocabulary skills, phonological awareness, and morphological awareness which would support decoding (and spelling) of mono- and multisyllabic words. Sensitivity to stress may also be directly associated with comprehension.

The contribution of 'intonation' to early reading development

Intonation, as defined by the editors of this volume, refers to a prosodic event (usually extended pitch contours) that extend over larger linguistic units e.g. at the sentence or discourse level. Wells (2006, p.11-12) identified several functions of intonation, including ‘attitudinal’ (to convey shock, surprise, anger, sarcasm etc.); ‘grammatical’ (structures to distinguish clause types such as question vs. statement); ‘focusing’ (pragmatic functions to bring some parts of the message to the fore and not others); ‘discourse’ (how sequences and clauses go together in spoken discourse to signify whether we are finished making a point or whether we want the other speaker to have a turn etc.); ‘psychological’ (to organize speech into units that aid performance, perception, memory); and ‘indexical’ (to mark personal or social identity such as the voice of a mother or news reader, for example). It is also noteworthy that in some languages (e.g., Chinese) different tones applied to the same syllable can represent different meanings, and a literature has shown that lexical tone sensitivity is related to children’s word reading in Chinese (e.g., McBride-Chang, Tong et al. 2008; Shu, Peng, & McBride-Chang 2008). This chapter will focus on suprasegmental phonology in the English language, where intonation does not have a lexical function.

In contrast to the suprasegmental component of stress, the mechanisms connecting the perception of intonation and early reading are less well-understood. It is also evident that the sparse literature available has focused mostly on the ‘production’ of intonation, although there are a few notable exceptions which found associations between pitch perception, phonological awareness, and reading (see Anvari, Trainor, Woodside, & Levy, 2002; Lamb & Gregory, 1993). For instance, in an early study, Clay and Imlach (1971) observed that proficient readers appropriately end declarative sentences with a fall in pitch. This finding has been replicated in other studies (see Miller & Schwanenflugel, 2006; Schwanenflugel et al., 2004) which have also shown that skilled readers appropriately end yes-no questions with a rise in pitch (see Miller & Schwanenflugel, 2006; also see Schwanenflugel, this volume). It has been argued that appropriate intonation (and phrasing more generally) might facilitate reading by linking together fluency and comprehension (see Kuhn & Stahl, 2003) and by adding meaning to the speech signal (Ravid & Mashraki, 2007; Whalley and Hansen, 2006; also see Schwanenflugel, this volume).

In summary, this section has shown that the ‘perception’ of intonation has generally been overlooked in its relationship to early reading. However, it might be inferred that ‘sensitivity to’ intonation (and other suprasegmental features) in listening and being able to transfer these skills to reading may support an individual’s understanding of meaning (comprehension).

The contribution of ‘timing’ to early reading development

The final suprasegmental component to be considered in this chapter is that of perceptual timing (or temporal variables), which can include rate, timing precision, and serial order (Wolff, Michel, Ovrut, & Drake, 1990).

Since the 1980s the potential link between perceptual timing (temporal-sequence processing in particular) and reading (including developmental dyslexia) has received ‘considerable attention’ (Breznitz & Share, 2002, p.1). Indeed, a literature has shown that children with reading difficulties often have problems processing temporal information. For example, Wolff (2002) found that dyslexic children had greater difficulty than their non-dyslexic counterparts on measures of motor sequencing (anticipation), manual motor rhythms (timing), speech rhythm (reproduction), and the ordering of syllables. Moreover, in a series of studies by Overy (see Overy, 2000; Overy, Nicolson, Fawcett, & Clarke, 2003) children with, or ‘at strong risk’ of, dyslexia, were outperformed by their non-dyslexic counterparts on a range of musical aptitude tests involving timing e.g. rhythm copying, rhythm discrimination, and song rhythm. The relationship between perceptual timing and reading has also been demonstrated in other recent studies using non-dyslexic samples (e.g., David, Wade-Woolley, Kirby, & Smithrim, 2007; Holliman et al., 2010b).

It is noteworthy that despite the evidence linking perceptual timing and reading there are unresolved questions concerning just how pervasive timing deficits are in relation to reading difficulties. For instance, Overy et al. (2003, p.19) point out that timing deficits (in relation to reading difficulties) have been explained via problems concerning visual and auditory perception, motor coordination, and fluency and automation; thus, via a range of domains. There has also been some debate concerning the extent to which speech and non-speech timing (and speech and non-speech rhythm more generally) represent related components of the same skill (see McMullen & Saffran, 2004, and Patel, 1998, for some related discussion on rhythmic processing). Moreover, recent research from cognitive neuroscience examining the role oscillatory networks in the auditory cortex (see Goswami, 2012; also see Goswami, this volume) suggests that metrical structure is core to both musical (non-speech) and linguistic (speech) domains and that both may result from general perceptual mechanisms that are neither specific to music (non-speech) nor language (Trehub & Hannon, 2006). A detailed examination of the pervasiveness of timing deficits in relation to reading difficulties is beyond the scope of this chapter; however, there is reason to suspect that the timing deficits observed using non-speech paradigms may extend to the domain of speech.

Timing deficits (e.g., speech, non-speech, and motor rhythm etc.) in relation to reading difficulties have most commonly been explained via a ‘domain-general’ dysfunction in processing temporal information (Tallal, 1980, 1984). Temporal processing generally refers to the temporal properties of the events, such as duration, sequencing, and rhythm, and it has been argued that the perception of these characteristics might be related to phonological processing. For example, Farmer and Klein (1995) argued that:

> ...if a temporal processing deficit contributes to a difficulty with perception and discrimination of phonemes, recognition of those phonemes will not occur as easily and automatically as it would in a subject without a temporal processing deficit. Such an impaired recognition would undoubtedly lead to many of the problems described in children with a phonemic deficit who are at risk for reading problems.
>
> (p. 480)

Research continues to investigate whether difficulties in rhythmic timing perception underpin reading difficulties and this has resulted in the development of reading intervention studies targeting rhythmic timing (see Goswami, 2013; also see Goswami, this volume). However, it should be noted that the link between timing and phonological skills has not been demonstrated in all studies. For example, using an adult sample, Chiappe, Stringer, Siegel, and Stanovich (2002) found that timing tasks and measures of phonological sensitivity shared little variance and that timing was also unable to account for much unique variance in reading.

To explain such contrary findings on the relationship between timing (temporal processing) and reading skills, Bishop and McArthur (2005, p.328) argued that "if auditory deficits are seen in only a subset of individuals, then one may mask genuine group differences by combining heterogeneous cases". Indeed, the argument that auditory temporal processing deficits may only be prevalent in a subset of children with reading difficulties (40% according to Ramus, 2003) has been echoed by earlier evidence (e.g., Wolff et al., 1990) and more recent observations by researchers in the field (see Thomson, 2009).

In summary, this section has shown that the perception of timing information may be related to early reading and may also support a range of associated skills such as vocabulary and phonological processing. However, it is important to note that this literature is hardly unequivocal and it has also been argued that perceptual timing deficits may not be prevalent in all children with reading difficulties.

It can be seen more generally from the chapter so far, that there is a theoretical and empirical evidence base linking each of the suprasegmental components (stress, intonation, and timing) to early reading skills, although this literature is not equally proportioned. It can also be observed that only a handful of studies have manipulated and/or measured different components of suprasegmental phonology in a non-delineated fashion which, as noted previously, has prevented any kind of examination of the relatedness of these components and their relative/comparative contribution to early reading development.

A new, multi-component measure of suprasegmental phonology

As noted, in the literature, there are few (if any) measures of suprasegmental phonology that provide an individual assessment of each of the different suprasegmental components (i.e., stress, intonation, and timing). In fact, few studies have even assessed sensitivity to the different suprasegmental components using a range of assessments (although see Holliman, Wood, and Sheehy, 2012). Such an assessment would enable us to explore the inter-relationships between stress, intonation, and timing and also investigate the ways in which each component relates to a range of early reading skills. In an attempt to develop one of the first assessments of the different suprasegmental components the Dina the Diver Task was designed and produced (Holliman, Williams et al., in press).

All aspects of this task involved a fictional character, Dina, who was depicted either entering or exiting the water in a cartoon diving scene. Dina produced a whole range of pre-recorded utterances which were always of easily recognisable characters (e.g., Godzilla) or scenes (e.g., Goldilocks likes porridge) from UK children's television and literature. When Dina was depicted outside the water, the utterances were clearly and correctly spoken, but when she was under the water, the utterances were low-pass filtered (removing any phonemic content but preserving the rhythmic contour of the utterance) and perceived as 'muffled'. This effect was achieved using Sound Forge

Audio Studio 9.0. The utterances were often accompanied by character cards of the characters or scenes to make the task more understandable to young children. The task format differed depending on which suprasegmental component was being measured.

The suprasegmental component of ‘stress’ was assessed using trials inspired by Wood and Terrell’s (1998) Sentence Matching Task and Whalley and Hansen’s (2006) Deedee Task. In each trial, children were presented with two character cards (or popular scenes from children’s television or literaure) and then heard two correctly spoken utterances (words, phrases, or sentences) which depicted those characters (or scenes). Each pair of utterances had a particular (and different) arrangement of stressed/unstressed syallables e.g. Dogtanian (weak-strong-weak) and Scoobydo (strong-weak-strong). This was then followed by a low-pass filtered utterance which matched just one of the correctly spoken utterances, and children had to match the low-pass filtered utterance to the correctly spoken utterance.

The suprasegmental component of ‘intonation’ was assessed using trials inspired by Hadding and Studdert-Kennedy (1974) among others. In each trial, children were presented with a single character card (or scene) and then heard a correctly spoken utterance (word, phrase, or sentence) which depicted that character (or scene). However, the utterance was produced in one of two ways; either with a rise in intonation at the end to imply a ‘question’ (e.g., /Winnie the Pooh) or with a fall in intonation at the end to imply a ‘statement’ (e.g., \Winnie the Pooh), and children had to decide whether they were being ‘told’ (statement) about the character/scene or whether they were being asked (question) about it.

The suprasegmental component of syllable ‘timing’ was assessed using trials inspired by a great number of studies using the ‘same-different’ paradigm. In each trial, children heard two low-pass filtered utterances (words, phrases, or sentences) depicting a character or scene. On some trials, the two utterances were produced in exactly the same way (e.g., The Lion King-The Lion King) while on other trials they differed in terms of syllable duration (e.g., The Lion King-The Liiiiion King), and children had to decide whether the two utterances were the ‘same’ or ‘different’. The syllable lengthening effect in the ‘different’ conditions was achieved by editing the low-pass filtered utterance using PRAAT 4.0.7 (Boersma, 2001).

In each trial, there were two practice trials and 15 test trials assessing sensitivity to each suprasegmental component of stress, intonation, and timing. Two experiments to date have adopted this task and investigated its relationship with a range of early reading skills and these studies will now be presented in turn, but will be discussed together under a ‘general discussion’.

Experiment 1: A multi-component measure of suprasegmental phonology and its relationship with vocabulary, phonological awareness, morphological awareness, word reading, and spelling[1]

In the experiment reported here, we draw upon some unpublished data from Holliman, Critten et al. (submitted) to explore: 1) how the different suprasegmental components relate to each other, and how each relate to measures of vocabulary, phonological awareness, morphological awareness, word reading, and spelling, and 2) whether the different suprasegmental components make a unique contribution to vocabulary skills, phonological awareness, morphological awareness, word reading, and spelling.

Method

All participants in this study (N = 75) were recruited from a single infant school in the West Midlands, UK. Children were aged between five- and seven-year-olds (mean age 6.2) and were in either Year One (n = 37) or Year Two (n = 38) classes. All of the males (n = 39) and females (n = 36) who took part had English as their first language.

In addition to the assessment of suprasegmental phonology (the Dina the Diver Task), discussed earlier, the following measures of vocabulary, phonological awareness, morphological awareness, reading, and spelling were used:

- **Vocabulary** was measured using the British Picture Vocabulary Scales II (Dunn, Dunn, Whetton & Burley, 1997);
- **Phonological awareness** was measured using the Rhyme Detection subtest of the Phonological Assessment Battery (Frederickson, Frith, & Reason, 1997) and the Phoneme Deletion task (Wood, 1999);
- **Morphological awareness** was measured using the Morphology Task (Duncan, Casalis, & Cole 2009);
- **Word reading** was measured using the British Ability Scales II Word Reading subtest (Elliot, Smith, & McUlloch, 1996);
- **Spelling** was measured using the Single Word Spelling Test (Sacre & Masterson, 2000).

Results

The mean raw scores on all standardized assessments in this study equated to a mean standardized score in the ‘average score’ range. On the Dina the Diver Task performance was significantly above chance on all suprasegmental components (stress, intonation, and timing).

1. How do the different suprasegmental components relate to each other, and how do each relate to measures of vocabulary, phonological awareness, morphological awareness, word reading, and spelling?

Bivariate correlations between sensitivity to the different components of suprasegmental phonology and measures of vocabulary, phonological awareness, morphological awareness, reading, and spelling are presented in Table 1.

<TABLE 1 NEAR HERE>

It can be seen from Table 1 that none of the suprasegmental components (stress, intonation, and timing) were significantly correlated with each other. However, stress was found to be significantly correlated with all other measures (with the exception of phoneme deletion: r = .196, p = .093) and was most strongly correlated with the measures of vocabulary (*r* = .396, *p* < .001) and morphological awareness (*r* = .347, *p* = .002). Intonation was found to be significantly correlated with all measures in this study and was most strongly correlated with the literacy measures: word reading (*r* = .514, *p* < .001) and spelling (*r* = .493, *p* < .001) and the measure of rhyme awareness (*r* = .463, *p* < .001). Timing was also found to be significantly correlated with all measures (with the exception of morphological awareness: *r* = .206, *p* = .076) and was most strongly correlated with the measure of vocabulary (*r* = .426, *p* < .001).

2. Can the different suprasegmental components make a unique contribution to vocabulary skills, phonological awareness, morphological awareness, word reading, and spelling?

To investigate whether the different suprasegmental components of stress, intonation, and timing can predict vocabulary skills, phonological awareness (rhyme awareness and phoneme awareness), morphological awareness, word reading, and spelling (independently of one and other), a series of standard multiple regressions analyses were conducted (see Table 2). In each of the following regressions preliminary analyses were conducted to ensure that the data met the assumptions for a multiple regression analysis.

<TABLE 2 NEAR HERE>

In the first standard multiple regression analysis (predicting vocabulary), it was found that 29.2% of the variance in vocabulary was explained by the three suprasegmental components (standard error of estimate was 9.379) and this was significant, *F*(3, 71) = 11.194, *p* < .001. An examination of the individual regression coefficients for each suprasegmental component showed that timing was able to make the strongest unique contribution to vocabulary, *Beta* = .344, *t*(71) = 3.429, *p* = .001, followed closely by stress, *Beta* = .318, *t*(71) = 3.195, *p* = .002. However, intonation was unable to make a significant unique contribution.

In the second and third multiple regression analyses (predicting phonological awareness: rhyme and phoneme), it was found that 32% of the variance in rhyme awareness was explained by the three suprasegmental components (standard error of estimate was 3.098) and this was significant, *F*(3, 71) = 12.596, *p* < .001. However, just 13.6% of the variance in phoneme awareness was explained by the three suprasegmental components (standard error of estimate was 4.499), although this was still statistically significant, *F*(3, 71) = 4.891, *p* = .004. An examination of the individual regression coefficients showed that all three suprasegmental components made a unique contribution to rhyme awareness: intonation (*Beta* = .388, *t*(71) = 3.969, *p* < .001); timing (*Beta* = .279, *t*(71) = 2.84, *p* = .006); stress (*Beta* = .205, *t*(71) = 2.097, *p* = .04), but only timing was able to make a significant unique contribution to phoneme awareness, *Beta* = .282, *t*(71) = 2.541, *p* = .013.

In the fourth analysis (predicting morphological awareness), it was found that 20.1% of the variance in morphological awareness was explained by the three suprasegmental components (standard error of estimate was 4.493) and this was significant, *F*(3, 71) =

7.223, $p < .001$. An examination of the individual regression coefficients showed that intonation made the strongest unique contribution to morphological awareness, *Beta* = .306, $t(71) = 2.891$, $p = .005$, followed closely by stress, *Beta* = .291, $t(71) = 2.752$, $p = .008$. However, timing was unable to make a significant unique contribution.

In the fifth analysis and sixth analysis (predicting reading and spelling respectively), it was found that 29.8% of the variance in word reading was explained by the three suprasegmental components (standard error of estimate was 17.095) and this was significant, $F(3, 71) = 11.471$, $p < .001$. Moreover, 30.3% of the variance in spelling was explained by the three suprasegmental components (standard error of estimate was 8.371) and this was significant, $F(3, 71) = 11.726$, $p < .001$. An examination of the individual regression coefficients showed that intonation made the strongest unique contribution to word reading, *Beta* = .466, $t(71) = 4.693$, $p < .001$, followed by stress, *Beta* = .205, $t(71) = 2.066$, $p = .042$. Intonation also made the strongest unique contribution to spelling, *Beta* = .433, $t(71) = 4.375$, $p < .001$, followed again by stress, *Beta* = .203, $t(71) = 2.056$, $p = .043$. However, timing was unable to make a significant unique contribution to reading or spelling in this study.

Experiment 2: A multi-component measure of suprasegmental phonology and its relationship with IQ, phonological awareness and decoding, passage reading accuracy, and reading comprehension[2]

In the experiment reported here, we draw upon some unpublished data from Holliman, Williams et al. (in press) to explore: 1) how the different suprasegmental components relate to each other, and how each relate to measures of vocabulary, phonological processing, passage reading accuracy, and reading comprehension, and 2) whether the different suprasegmental components make a unique contribution to vocabulary skills, phonological processing, passage reading accuracy, and reading comprehension.

Method

All participants in this study ($N = 62$) were recruited from a single primary school in the West Midlands, UK. Children were aged between five- and seven-year-olds (mean age 6.3) and were in either Year One ($n = 27$) or Year Two ($n = 35$) classes. All of the males ($n = 30$) and females ($n = 32$) who took part had English as their first language.

In addition to the assessment of suprasegmental phonology (the Dina the Diver Task), discussed earlier, the following measures of general ability, phonological processing, and literacy were used:

- **Non-verbal IQ** was measured using the Coloured Progressive Matrices subtest of Raven's IQ scale (Raven & Rust, 2008);
- **Vocabulary** was measured using the Crichton Vocabulary Scale subtest of Raven's IQ scale (Raven & Rust, 2008);
- **Phonological awareness** was measured using the Rhyme Detection subtest of the Phonological Assessment Battery (Frederickson et al., 1997);
- **Phonological decoding** was measured using the Non-Word Reading subtest from the Phonological Assessment Battery (Frederickson et al., 1997);

- **Passage reading accuracy** was measured using the Revised Neale Analysis of Reading Ability (Neale, 1997);
- **Reading comprehension** was measured using the Revised Neale Analysis of Reading Ability (Neale, 1997).

Results

The mean raw scores on all assessments in this study equated to a mean standardized score in the 'average score' range. On the Dina the Diver Task performance was significantly above chance on the suprasegmental components of intonation and timing, but not stress, and this is discussed later.

1. How do the different suprasegmental components relate to each other, and how do each relate to measures of vocabulary, phonological processing, passage reading accuracy, and reading comprehension?

Bivariate correlations between sensitivity to the different components of suprasegmental phonology and measures of non-verbal IQ, vocabulary, phonological processing, and literacy are presented in Table 3.

<TABLE 3 NEAR HERE>

It can be seen from Table 3 that the suprasegmental component of stress was significantly correlated with the suprasegmental component of intonation (r = .311, p = .014). However, the suprasegmental component of timing was not significantly correlated with stress (r = .093, p = .471) or intonation (r = .128, p = .321). Stress was found to be significantly correlated with measures of vocabulary (r = .266, p = .037) and phonological awareness (rhyme detection r = .345, p = .006), as expected, but not phonological decoding (non-word reading). Stress was also found to be significantly correlated with the literacy measures: passage reading accuracy (r = .263, p = .039) and reading comprehension (r = .304, p = .016). Intonation was found to be significantly correlated with measures of phonological processing: rhyme detection r = .419, p = .001 and non-word reading r = .347, p = .006, and with measures of literacy: passage reading accuracy (r = .331, p = .009) and reading comprehension (r = .344, p = .006), but not with the general ability measures. Timing was found to be significantly correlated with measures of vocabulary (r = .431, $p < .001$) and reading comprehension (r = .288, p = .023) only.

2. Can the different suprasegmental components make a unique contribution to vocabulary skills, phonological processing, passage reading accuracy, and reading comprehension?

To investigate whether the different suprasegmental components of stress, intonation, and timing can make a 'unique' contribution to vocabulary skills, phonological awareness, phonological decoding, passage reading accuracy, and reading comprehension, a series of standard multiple regressions analyses were conducted (see Table 4). For each, it was ensured that the data met the assumptions for a multiple regression.

<TABLE 4 NEAR HERE>

In the first standard multiple regression analysis (predicting vocabulary), it was found that 21.3% of the variance in vocabulary was explained by the three suprasegmental components (standard error of estimate was 6.084) and this was significant, $F(3, 58) = 6.51$, $p = .001$. However, an examination of the individual regression coefficients for each suprasegmental component revealed that only timing was able to make a significant unique contribution, *Beta* = .397, $t(58) = 3.461$, $p = .001$.

In the second and third multiple regression analyses (predicting phonological processing: rhyme and phonological decoding), it was found that 20.4% of the variance in rhyme awareness was explained by the three suprasegmental components (standard error of estimate was 4.941) and this was significant, $F(3, 58) = 6.217$, $p = .001$. A lesser 12.5% of the variance in phonological decoding was explained by the three suprasegmental components (standard error of estimate was 4.053), but this was still statistically significant, $F(3, 58) = 3.904$, $p = .013$. An examination of the individual regression coefficients showed that only intonation was able to make a significant unique contribution to rhyme awareness, *Beta* = .331, $t(58) = 2.738$, $p = .008$ and phonological decoding, *Beta* = .296, $t(58) = 2.337$, $p = .023$, although the contribution of stress in predicting rhyme awareness was only marginally non-significant, *Beta* = .23, $t(58) = 1.912$, $p = .061$.

In the fourth and fifth analysis (predicting passage reading accuracy and reading comprehension respectively) it was found that just 12.7% of the variance in passage reading accuracy was explained by the three suprasegmental components (standard error of estimate was 1.906), although this was still statistically significant, $F(3, 58) = 3.971$, $p = .012$. In predicting reading comprehension, it was found that 17.6% of the variance in reading comprehension was explained by the three suprasegmental components (standard error of estimate was 4.351) and this was significant, $F(3, 58) = 5.341$, $p = .003$. An examination of the individual regression coefficients showed that only intonation was able to make a significant unique contribution to passage reading accuracy, *Beta* = .256, $t(58) = 2.021$, $p = .048$. Intonation was also found to make the strongest unique contribution to reading comprehension, *Beta* = .25, $t(58) = 2.036$, $p = .046$, although timing was also able to make a significant unique contribution, *Beta* = .236, $t(58) = 2.014$, $p = .049$. Stress was unable to account for unique variance in passage reading accuracy or reading comprehension in this study.

General discussion of Experiment 1 and 2

One of the first exploratory questions in Experiment 1 and 2 was whether the different suprasegmental components (i.e., stress, intonation, and timing) were significantly correlated with each other. It was found (with the exception of the stress-intonation relationship in Experiment 2) that the different suprasegmental components were not significantly correlated. Not only were the correlations non-significant, they were not strong (i.e., $r < .2$). This suggests that performance on one suprasegmental component is not predictive of performance on another component. Indeed, in a factor analysis related to the dataset in Experiment 2 (not reported here, see Holliman, Williams et al., in press) it was found that differences in the type of suprasegmental information manipulated across conditions (i.e., stress, intonation, and timing) had a stronger influence on the factor structure than variation in the size of linguistic units (i.e., word-, phrase-, or sentence-level). However, as acknowledged by the authors, it is possible that differences in task format may also have contributed to the factor structure here; that is, the stress task was an 'identification' task, the intonation task was a 'categorization' task, and the timing task was a 'discrimination' task.

These findings may suggest that the different suprasegmental components cannot be considered as part of a unitary construct. However, it is noteworthy that even in published UK assessments of phonological processing (e.g., the Phonological Assessment Battery, PhAB, Frederickson et al., 1997), which was used with much larger samples, the different components do not always correlate strongly or significantly with each other (see Frederickson et al., 1997). For the PhAB, it is quite possible that the phonological processing assessments 'in combination' are a far more reliable predictor of literacy than any individual component; thus, the whole may be greater than the sum of its parts. It is possible that the processing of suprasegmental phonology may follow a similar pattern and that perhaps by disentangling the different components and assessing them separately (as has been done in this chapter) we could be clouding the 'combined' effect, which may in fact be far stronger than that of any individual component. In support of this idea, in relation to the dataset in Experiment 1, Holliman, Critten et al. (submitted) found much stronger and more significant relationships between a composite measure of suprasegmental phonology and early reading skills than those observed for each individual component, reported here.

We will now consider another exploratory question in Experiment 1 and 2, which considers how the different suprasegmental components are related to the range of reading skills that were employed across the two experiments. Overall, from the bivariate correlation analyses, it can be observed that the different components of suprasegmental phonology (stress, intonation, and timing) were significantly correlated with almost all other variables in Experiment 1, and in Experiment 2 to a lesser extent. Even when the relationship was non-significant it was rarely too far away from an alpha of .05. These findings are generally consistent with the literature presented in earlier sections of this chapter which demonstrate associations between the different suprasegmental phonological components and a range of reading-related skills. We will now consider the findings relating to each suprasegmental component in turn.

In both Experiment 1 and 2, sensitivity to stress was found to correlate significantly with vocabulary; this provides support for the idea that sensitivity to stress might facilitate spoken word recognition (Cutler & Carter, 1987; Cutler and Norris, 1988), which will ultimately facilitate vocabulary growth. Stress was also found to be significantly correlated with rhyme awareness in both experiments; this could be explained by the fact that peak of loudness in a syllable corresponds to vowel location (Scott, 1998) which may support the identification of onset-rime boundaries (see Goswami et al., 2002). Surprisingly, stress was not found to be correlated with other measures of phonological processing such as phoneme deletion and non-word reading. Moreover, sensitivity to stress was found to correlate significantly with morphology (as expected based on the literature e.g., Clin et al., 2009) along with the various reading measures employed across the two experiments, and these findings were in line with expectations based on the theory and evidence presented earlier in this chapter. Sensitivity to stress was also found to be a unique predictor of these skills (based on the results from the standard multiple regression analyses).

Sensitivity to intonation was found to correlate significantly with almost all variables across Experiment 1 and 2; indeed, the largest effect sizes were observed for the suprasegmental component of intonation rather than for stress or timing. Intonation was found to correlate significantly with measures of phonological processing (consistent with the findings in Anvari et al., 2002; Lamb & Gregory, 1993) and could do so independently of its association with the other suprasegmental components. Intonation was also found to be significantly correlated with the various literacy measures (e.g., single word reading, passage reading accuracy, spelling, and reading comprehension), which was in line with the literature making interconnections between decoding, comprehension, and intonation in particular (e.g., Clay & Imlach, 1971; Kuhn & Stahl, 2003; Miller & Schwanenflugel, 2006; Ravid & Mashraki, 2007; Schwanenflugel et al., 2004). Interestingly, intonation was able to account for unique variance in these reading skills often when the other suprasegmental components became non-significant, which may suggest in line with Anvari et al. (2002) that pitch (intonation) may be distinct from other rhythmic components in terms of its relationship with early reading skills.

Sensitivity to timing was found to be the best predictor of vocabulary in both experiments. The strong association between timing and vocabulary were in line with other studies (e.g., Holliman et al., 2010b). The association between sensitivity to timing and phonological awareness was mixed across the two experiments: in Experiment 1, timing was significantly associated with rhyme awareness and phoneme deletion sometimes independently of its association with stress and intonation. However, in Experiment 2, timing was not significantly correlated with the phonological processing measures. These mixed findings are consistent with a mixed literature in which timing has (e.g., Holliman et al., 2010b) and has not (e.g., Chiappe et al., 2002) been associated with phonological skills. This may, in part, be attributable to the idea that temporal deficits may only be prevalent in a subsample of children with reading difficulties (Bishop & McArthur, 2005; Ramus, 2003; Thomson, 2009; Wolff et al., 1990). Timing was also found to be related to most of the reading measures (e.g., single word reading, spelling, and reading comprehension) and this was also consistent with the literature (David et al., 2007; Holliman et al., 2010; Overy, 2000; Overy et al., 2003; Wolff, 2002).

Methodological limitations

There are several methodological limitations in the research reported here that will now be acknowledged. First, it was regrettable that performance on the ‘stress’ component of the Dina the Diver Task (in Experiment 2) was not significantly above chance – therefore we cannot be certain that participating children understood this component of the task. Second, the suprasegmental component of ‘intonation’ was only assessed by manipulating the ‘grammatical function’ to distinguish between questions and statements; however, there are many other functions of intonation in the English language that were not assessed (see Wells, 2006, p.11-12). Third, some aspects of the

Dina the Diver Task (e.g., phrasing and sentencing) were memory intensive; however, see point one. Fourth, given that we do not have fully mapped out developmental trajectories for the different suprasegmental components (stress, intonation, and timing) knowing whether we are measuring these constructs at an 'equivalent' level of difficulty remains unknown. Fifth, and related to point four, it is also possible that suprasegmental phonological abilities differ throughout the period of reading development and therefore different aspects of such abilities may contribute at different time points. This signified the importance of large-scale longitudinal research, which is much needed in this area.

Conclusion

In sum, this chapter has provided further support for the important role of suprasegmental phonology in early reading development – an argument no doubt echoed by authors across this volume. However, this chapter has also opened up an important question for debate – should we continue to consider 'suprasegmental phonology' as a unitary construct where individual components are assessed in a non-delineated fashion, but conceived to be different elements of the same underlying skill or should we begin to disentangle suprasegmental phonology theoretically, and practically in order to develop a more sophisticated understanding of its role (and the role of its constituent parts) in early reading development? What is clear, based on the research evidence and theory presented in this chapter, is that the different components of suprasegmental phonology may not be correlated and may be related to reading development in different ways. However, it is also likely and evident (see Holliman, Critten et al., submitted) that early reading skills are best-predicted when more holistic, composite measures of suprasegmental phonology are employed than when individual components are selected, which may indicate that the whole (suprasegmental phonology) is greater than the sum of its parts (stress, intonation, and timing).

The link between suprasegmental phonology and early reading skills is no longer a novel finding; this is supported by converging evidence synthesized in this volume. However, the way in which we conceptualize suprasegmental phonology, its constituent parts, and how we go about measuring these in relation to early reading skills, requires more attention in the field.

Notes

1. Holliman, A. J., Critten, S., Lawrence, T., Harrison, E. C. J., & Wood, C. (unpublished data).

2. Holliman, A. J., Williams, G. J., Mundy, I. R., Wood, C., Hart, L., & Waldron, S. (unpublished data).

Acknowledgments

The author gratefully acknowledges the support from the British Academy for funding the research relating to the second unpublished dataset above (Experiment 2) and for

funding the measure that was used in the first unpublished dataset above (Experiment 1).

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Table 1. *Correlation matrix between the different components of suprasegmental phonological sensitivity using the multi-component measure (MCP), vocabulary, phonological awareness, morphological awareness, word reading, and spelling.*

Variables	Stress (MCP)	Intonation (MCP)	Timing (MCP)
Stress (MCP)	-	-	-
Intonation (MCP)	.127	-	-
Timing (MCP)	.163	.173	-
Vocabulary	.396***	.275*	.426***
Rhyme Detection	.3**	.463***	.38**
Phoneme Deletion	.196	.263*	.336**
Morphology	.347**	.362**	.206
Word Reading	.284*	.514***	.236*
Spelling	.29*	.493***	.303**

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

Table 2: *Multiple regression analysis predicting vocabulary, phonological awareness, morphological awareness, word reading, and spelling from stress, intonation, and timing.*

Independent Variable	β	*t*	Sig
Predicting Vocabulary			
Stress	.318	3.195	.002
Intonation	.175	1.757	.083
Timing	.344	3.429	.001
Predicting Rhyme Awareness			
Stress	.205	2.097	.040
Intonation	.388	3.969	.000
Timing	.279	2.840	.006
Predicting Phoneme Awareness			
Stress	.125	1.132	.261
Intonation	.198	1.798	.076
Timing	.282	2.541	.013
Predicting Morphological Awareness			
Stress	.291	2.752	.008
Intonation	.306	2.891	.005
Timing	.106	.993	.324
Predicting Word Reading			
Stress	.205	2.066	.042
Intonation	.466	4.693	.000
Timing	.122	1.217	.228
Predicting Spelling			
Stress	.203	2.056	.043
Intonation	.433	4.375	.000
Timing	.194	1.952	.055

Table 3. *Correlation matrix between the different components of suprasegmental phonological sensitivity using the multi-component measure (MCP), IQ, phonological awareness and decoding, passage reading accuracy, and reading comprehension.*

Variables	Stress (MCP)	Intonation (MCP)	Timing (MCP)
Stress (MCP)	-	-	-
Intonation (MCP)	.311*	-	-
Timing (MCP)	.093	.128	-
Non-verbal IQ	.11	.166	.149
Verbal IQ	.266*	.238	.431***
Rhyme Detection	.345**	.419**	.194
Non-Word Reading	.192	.347**	.246†
Passage Reading	.263*	.331**	.231
Reading Comprehension	.304*	.344**	.288*

Note: †p=.05, *p<.05, **p<.01, ***p<.001

Table 4: *Multiple regression analysis predicting vocabulary, phonological processing, passage reading accuracy, and reading comprehension from stress, intonation, and timing.*

Independent Variable	β	*t*	Sig
Predicting Vocabulary			
Stress	.189	1.576	.121
Intonation	.129	1.071	.288
Timing	.397	3.461	.001
Predicting Rhyme Awareness			
Stress	.230	1.912	.061
Intonation	.331	2.738	.008
Timing	.130	1.127	.264
Predicting Phonological Decoding			
Stress	.081	.645	.521
Intonation	.296	2.337	.023
Timing	.201	1.660	.102
Predicting Passage Reading			
Stress	.166	1.318	.193
Intonation	.256	2.021	.048
Timing	.183	1.511	.136
Predicting Reading Comprehension			
Stress	.204	1.669	.101
Intonation	.250	2.036	.046
Timing	.236	2.014	.049