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Effects of metric hierarchy and rhyme predictability on word duration in *The Cat in the Hat*

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ABSTRACT

Word durations convey many types of linguistic information, including intrinsic lexical features like length and frequency and contextual features like syntactic and semantic structure. The current study was designed to investigate whether hierarchical metric structure and rhyme predictability account for durational variation over and above other features in productions of a rhyming, metrically-regular children's book: *The Cat in the Hat* (Dr. Seuss, 1957). One-syllable word durations and inter-onset intervals were modeled as functions of segment number, lexical frequency, word class, syntactic structure, repetition, and font emphasis. Consistent with prior work, factors predicting longer word durations and inter-onset intervals included more phonemes, lower frequency, first mention, alignment with a syntactic boundary, and capitalization. A model parameter corresponding to metric grid height improved model fit of word durations and inter-onset intervals. Specifically, speakers realized five levels of metric hierarchy with inter-onset intervals such that interval duration increased linearly with increased height in the metric hierarchy. Conversely, speakers realized only three levels of metric hierarchy with word duration, demonstrating that they shortened the highly predictable rhyme resolutions. These results further understanding of the factors that affect spoken word duration, and demonstrate the myriad cues that children receive about linguistic structure from nursery rhymes.

1. Introduction

Children's literature across languages contains many examples of metrically-regular, rhyming texts (Arleo, 2006; Brailoiu, 1984; Burling, 1966). Literacy experts have suggested that the structure of these texts enhances children's literacy development (e.g., Irwin, Moore, Tornatore, & Fowler, 2012), and publishers and educators tout nursery rhymes as ideal first readers. However, there is limited experimental evidence supporting the claim that these texts improve reading ability. To clarify the contribution that nursery rhymes make to early reading skill, we first need to understand what type of information readers of nursery rhymes are exposed to through their interaction with metrically-regular, rhyming texts, and how this information differs from prose. Moreover, because children routinely *hear* these texts before they read them, we need to understand how they are produced by readers. In the current study, I investigated how metric structure and rhyme in a classic children's book, *The Cat in the Hat* (Dr. Seuss, 1957), affect prosody in adult productions.

Despite the ubiquity of metrically-regular, rhyming children's books, there have been few systematic investigations of whether or how their productions differ from prose productions. What studies have been carried out have investigated to what extent the prosodic hierarchy (Hayes, 1989; Liberman & Prince, 1977; Nespor & Vogel, 1986; Selkirk, 1984) is realized in metric verse. The prosodic hierarchy is primarily determined by a sentence's phonological structure (Nespor & Vogel, 1986). Although it is correlated with syntactic structure, it is not identical to it (e.g., Gee & Grosjean, 1983; Shattuck-Hufnagel & Turk, 1996). The levels of the prosodic hierarchy are *words*, *clitic phrases*, which are groupings of words that tend to overlap in production, *phonological* or *accentual phrases*, which are domains within which speakers place accents, and *intonational phrases*, which are phrases bounded by tonal or temporal disjuncture. These levels have been argued to form a strict hierarchy, such that each level contains the only the level of the hierarchy beneath it (Hayes, 1989; Nespor & Vogel, 1986).

The prosodic hierarchy has been shown to influence production behavior for both prose and poetry. In prose contexts, speakers increase word duration with position in up to four levels of the prosodic hierarchy (Wightman, Shattuck-Hufnagel, Ostendorf, & Price, 1992). In addition, the prosodic hierarchy has been shown to account for durational variation of words in sentences matched on syntactic structure (Ferreira, 1993). In poetic contexts, speakers have been shown to produce syllables that align with higher levels of the hierarchy with longer

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durations than those that align with lower levels (Hayes & Kaun, 1996). However, although the prosodic hierarchy is correlated with the metric structure of text, it is not isomorphic with it. As such, there has been no systematic evaluation of the influence of hierarchical metric structure on speech. The goal of the current study is to provide such an evaluation.

One very well-known example of metrically-regular, rhyming text in English children's literature is *The Cat in the Hat* by Theodor Geisel (1957), published under Geisel's pen name Dr. Seuss. Geisel was given a list of 300+ words that every six-year-old should know, and used 236 unique words (220 of which were monosyllabic) mostly from that list to write the book (Nel, 2004). In an effort to make *The Cat in the Hat* a more entertaining reading primer than the standard "Dick and Jane" readers of the time, *The Cat in the Hat* is written primarily in anapestic tetrameter: lines (1A, 1B) consist of four anapestic (weak-weak-**strong**) feet. Two couplets form a stanza, and the last syllables of the two lines within a stanza (e.g., *all, fall*) rhyme.

(1) *A: "Put me **down**!" said the **fish**.*
*This is **no** fun at **all**!*
*B: Put me **down**!" said the **fish**.*
*"I do **NOT** wish to **fall**."*

To describe the metric structure of *The Cat in the Hat,* I utilized the metrical grid structure conventions of Fabb and Halle (2008), which are based in part on proposals by Liberman and Prince (1977) and Idsardi (1992). Under Fabb and Halle's (2008) proposal, syllables are assigned to a grid using a set of iterative rules. Fabb and Halle refer to the levels as "Gridlines" which start at level 0; for ease of interpretation, they are referred to as "Metric Levels" and begin numbering at level 1. The application of these rules to a stanza from *The Cat in the Hat* is presented in Table 1. First, each syllable, regardless of accent status, is assigned an asterisk on Metric Level 1. Next, syllables are grouped on Metric Level 2 using parentheses which face left or right depending on whether the metric feet are left-headed (i.e., with the heavy syllable on the left, including *trochees* and *dactyls*) or right-headed (i.e., with the heavy syllable on the right, including *iambs* and *anapests*). For lines composed of left-headed feet, syllables are grouped from left to right; for right-headed feet, syllables are grouped from right to left. Here I focus only on the rules for right-headed feet, as *The Cat in the Hat* is composed of anapests. To create Metric Level 2, the heads of Metric Level 1 are grouped into ternary right-headed structures which project their heads to Metric Level 2, as indicated by the location of asterisks on Metric Level 2. To generate groupings on Metric Level 3 and above, the heads on the Metric Level below are grouped into binary, right-headed groups, the boundaries of which are indicated by left-facing parentheses. For example, *down* is the head of a group on Metric Level 2, but *fish* is the head of the group containing *down* on Metric Level 3. The metric grid is complete when there is no way to decrease the number of asterisks on a gridline; that is, with a Metric Level containing only 1 asterisk. For the first line in Table 1, this condition is met at Metric Level 4.

Application of Fabb and Halle's (2008) iterative grouping rules to one line of *The Cat in the Hat* results in a metrical grid consisting of four hierarchical levels, and Fabb and Halle state that lines requiring four or more levels (i.e., with more than twelve syllables) are rare, perhaps due to memory constraints. However, metric structure in music is routinely computed over larger distances (Lerdahl & Jackendoff, 1983; Todd, 1985). In the current analyses, therefore, the iterative grouping rules are extended to two lines (i.e., one stanza) to test the hypothesis that readers generate metric grid structures that take into account more than one line of text. This extension results in five levels of metric structure (Table 1).

Fabb and Halle (2008) explicitly state that their model is not one of performance, in that they don't intend for it to predict speaker behavior or to account for the influence of other forms of linguistic knowledge on productions of metric structure. In fact, there have been few systematic investigations of how hierarchical metric structure is realized in speech, limited to the repetition of short (four-word) segments (Cummins & Port, 1998). However, there are two compelling reasons to believe that speakers will provide cues to metric structure in continuous speech: speakers realize many aspects of linguistic structure with prosody, and both experienced and novice musicians realize hierarchical metric structure in musical productions.

First, extensive empirical research demonstrates that speakers routinely signal aspects of linguistic structure using prosodic cues like prominence and phrasing (see reviews by Fletcher, 2010). For example, speakers signal the presence of new or important information with accents, characterized by longer duration (Fry, 1955; Klatt, 1976), greater intensity (Fry, 1955), and pitch movement (Breen, Fedorenko, Wagner, & Gibson, 2010). Moreover, speakers use durational lengthening to cue lexical boundaries (Beckman & Edwards, 1990; Turk & Shattuck-Hufnagel, 2000) and syntactic boundaries (Watson & Gibson, 2004; Wightman et al., 1992). Finally, and most relevant to the current investigation, speakers have been shown to use durational cues to maintain rhythmic structure in both prose speech (Beckman & Edwards, 1990; Cummins & Port, 1998; Lehiste, 1972) and poetic speech (Wagner, 2013).

Second, evidence from music performance demonstrates that musicians signal metric structure using a variety of acoustic features. For example, notes in metrically strong positions are produced with relatively longer durations than similar length notes in non-prominent positions (Clarke, 1985; Drake & Palmer, 1993; Palmer & Kelly, 1992; Repp, 1992; Sloboda, 1983). Moreover, metric structure affects durational variation at multiple hierarchical levels (Palmer, 1996; Todd,

Table 1
Metric grid assignment for one stanza of *The Cat in the Hat* based on Fabb and Halle (2008).

	Put	me	down	said	the	fish	this	is	no	fun	at	all
Metric Level 1	)*	*	*)	*	*	*)	*	*	*)	*	*	*)
Metric Level 2			)*			*)			*			*)
Metric Level 3						)*						*)
Metric Level 4												)*
Metric Level 5												
	Put	me	down	said	the	fish	I	do	not	wish	to	fall
Metric Level 1	)*	*	*)	*	*	*)	*	*	*)	*	*	*)
Metric Level 2			)*			*)			*			*)
Metric Level 3						)*						*)
Metric Level 4												*)
Metric Level 5												*

Note: Asterisks indicate syllables that head groups on the next-lowest metric level. Parentheses group syllables on a level; left-facing parentheses demarcate the boundaries of a right-headed group.