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Identifying the role of phonology in sentence-level reading

Dave Kush *, Clinton L. Johns, Julie A. Van Dyke

Haskins Laboratories, United States

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ABSTRACT

Phonological properties of the words in a sentence have been shown to affect processing fluency and comprehension. However, the exact role of phonology in sentence comprehension remains unclear. If constituents are stored in working memory during routine processing and accessed through their phonological code, phonological information may exert a pervasive influence on post-lexical comprehension processes such as retrieval for thematic integration. On the other hand, if access to constituents in memory during parsing is guided primarily by syntactic and semantic information, the parser should be isolated from phonologically based effects. In two self-paced reading experiments, we tested whether phonological overlap between distractors and a retrieval target caused retrieval interference during thematic integration. We found that phonological overlap creates difficulty during the initial encoding of the filler, but there was no evidence that phonological overlap caused later interference when the filler was retrieved for thematic integration. Despite effects at encoding, phonological interference did not have a detrimental effect on comprehension. These results suggest that phonological information is not used as a retrieval cue during routine dependency construction in incremental sentence processing. We conclude by considering the potential importance of phonology in parsing under conditions of extraordinary syntactic and/or semantic interference.

Introduction

Previous research revealing detrimental effects of phonological overlap among sentence constituents suggests that phonology may play a role in sentence comprehension. Specifically, participants' overall reading speed, and/or comprehension accuracy, can be impaired if a sentence contains phonologically similar constituents relative to sentences with identical syntactic structures whose constituents do not have phonological overlap (Acheson & MacDonald, 2011; Baddeley, Eldridge, & Lewis, 1981; Baddeley & Hitch, 1974; Haber & Haber, 1982; Keller, Carpenter, & Just, 2003; Kennison, 2004; Kennison, Sieck, & Briesch, 2003; McCutchen, Bell, France, & Perfetti, 1991; McCutchen, Dibble, & Blount, 1994; McCutchen & Perfetti, 1982; Robinson & Katayama, 1997; Zhang & Perfetti, 1993). However, in spite of this empirical record, the mechanism by which phonological overlap causes processing difficulty is uncertain. Furthermore, little is known about the time-course of these effects during incremental sentence processing because most previous studies employed methods that do not provide fine-grained temporal information. To our knowledge, there is only a single study (Acheson & MacDonald, 2011) that provides evidence that bears on the question of time course. In this study, processing difficulty arose *immediately after* encountering the first phonologically overlapping constituent. That is, despite having identical syntactic structures, reading times were slower for the three words that followed *banker* in phonologically overlapping sentences like (1a), as compared to those like (1b). Comprehension accuracy was also lower in overlapping conditions.

* Corresponding author at: Haskins Laboratories, 300 George St., New Haven, CT 06511, United States.
E-mail address: kush@haskins.yale.edu (D. Kush).

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(1a) The baker that the banker sought bought the house.
(1b) The runner that the banker feared bought the house.

Acheson and MacDonald suggested that one possible explanation for their result might derive from retrieval interference. Namely, they proposed that retroactive interference occurred at the integration site because phonological information was used during the retrieval of the displaced filler (e.g., *baker* in sentence 1a). It is not possible to evaluate this account based on the Acheson and MacDonald experiments, however, as the presence of phonological overlap throughout the sentence makes it impossible to determine whether the observed slowing occurred during *integration* of the verbs with their filler, or during the *encoding* of phonologically similar items. If interference occurs at encoding then phonology would have its central role at the level of perceptual encoding, which is consistent with evidence for the primacy of the phonetic code in storing verbal material (Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979), and for phonologically mediated lexical access (e.g., Desroches, Newman, & Joanisse, 2009; Lukatela & Turvey, 1994; Van Orden, 1987). However, if phonological interference manifests during thematic integration processes, as suggested by Acheson and MacDonald, then phonology must play a direct role in routine dependency-creation procedures (e.g., retrieval). This possibility would be surprising, as the relation between the segmental phonological code and the grammar is entirely arbitrary. Moreover, extant theories of sentence processing assume that parsing is primarily grammar-driven; we are not aware of any parsing theory that assigns a decisive role to segmental phonology.[1] Consequently, finding phonological interference during thematic integration would be highly significant.

Evaluating these two possibilities depends substantially on the memory model that is assumed to support incremental sentence processing. Under theories that posit a phonologically mediated working memory (WM) store, in which incremental sentence representations are actively maintained (e.g., those that store intermediate representations in Baddeley's *phonological loop*), phonology could have a pervasive influence on stages of sentence processing beyond lexical encoding. This approach predicts that phonological interference would manifest if phonologically similar or overlapping items are held in WM. Further, such interference should increase as a function of the number of overlapping items, especially if the parser requires that entire constituents be maintained in WM during the integration of grammatical dependents (e.g., Caramazza, Berndt, & Koller, 1981; Gibson, 2000; Shankweiler & Crain, 1986).

An alternative approach assumes a sharply limited focus of attention, which constitutes active memory (e.g., Lewis, Vasishth, & Van Dyke, 2006; McElree, Foraker, & Dyer, 2003). On this view, an item's initial encoding may rely on its phonological code, but it is then rapidly shuttled out of the focus of attention and into a general long-term memory (LTM), access to which is dominated by syntactic and semantic codes (cf. Bruce & Crowley, 1970; Kintsch & Buschke, 1969). Under this view, parsing does not require the simultaneous maintenance of numerous objects in a single WM store or the phonological loop, and the phonological form of displaced items is effectively inert for subsequent retrieval operations. Thus, these models predict that phonology's influence in incremental parsing should not extend past the encoding or lexical access stage. Phonologically overlapping distractors should not contribute to retrieval interference during later thematic integration because previously encountered (i.e., heard or read) items are accessed primarily via semantic and syntactic, but not phonological, cues.[2]

This paper aims to directly assess the role of phonology in retrieval and parsing by assessing whether phonological overlap can create retrieval interference. To accomplish this we used an experimental paradigm that has previously been used to demonstrate sensitivity to interference effects during incremental reading. Van Dyke and colleagues have shown that thematic integration of a filler with a verb is susceptible to interference from semantic associates (Van Dyke & McElree, 2006; Van Dyke, Johns, & Kukona, 2014; see also Gordon, Hendrick, & Levine, 2002). In a self-paced reading paradigm, participants were required to read sentences such as (2) in which a filler (e.g., *boat*) had to be interpreted as the object of a subsequent verb (e.g., either *sailed* or *fixed*). On half of the trials, participants also memorized a list of three distractor words (Load conditions), which they were asked to recall after completing the reading task and answering a subsequent comprehension question. The sentences in the NoLoad conditions were identical to those in the Load conditions, but these conditions were presented without a memory list. Interference was created in the Load conditions by manipulating the degree of overlap between the verb's affordances and the semantic properties of the distractor nouns. In Non-Interfering conditions, the semantic features of the verb uniquely resonated with the filler (*sailed* selects for *boat*). In Interfering conditions, both the target filler and the items in the memory load list were plausible objects of the verb (e.g., tables, sinks, trucks, and boats are all objects that can be *fixed*).

(2) {table–sink–truck}/{----- ----- -----}.

It was the boat that the guy who lived by the sea **{sailed/fixed}** in two sunny days.

Van Dyke and McElree (2006) reported a significant slowdown at the verb only when participants were required to memorize a set of items that were plausible objects for the critical verb. They reasoned that this was

[1] We acknowledge that suprasegmental phonology, such as prosodic phrasing, may play an important role in parsing, particularly in the presence of phrasal ambiguities. The current paper is concerned only with word-level phonological overlap, of the sort investigated by Acheson and MacDonald (2011) and the other studies cited in the introduction.

[2] It is not our position that phonological form is *absent* from the stored memory trace of a lexical item. Indeed, there is much evidence that lexical items are stored as integrated representations that include orthographic, phonologic, and semantic information (e.g., Harm & Seidenberg, 1999, 2004; Seidenberg & McClelland, 1989).