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Short Communication

Auditory morphological processing: Evidence from phonological priming

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ABSTRACT

Using an auditory lexical decision task, we find evidence of a facilitatory priming effect for morphologically complex targets (e.g., *snow-ed*) preceded by primes which rhyme with the target's stem (e.g., *dough*). By using rhyme priming, we are able to probe for morphological processing in a way that avoids confounds arising from semantic relatedness that are inherent to morphological priming (*snow*/*snow-ed*). Phonological control conditions (e.g., targets *code* and *grove* for prime *dough*) are used to rule out alternative interpretations of the effect that are based on partial rhyme or phonological embedding of the stem. The findings provide novel evidence for an independent morphological component in lexical processing and demonstrate the utility of rhyme priming in probing morphological representation.

1. Introduction

1.1. Background

A central issue in the study of the mental lexicon is whether hypothetical morphological representations are activated during real-time processing: Is there independent representation and processing of morphological information or can morphological effects be reduced to interactions between phonology and semantics? In addition to a literature examining frequency effects (see Ford, Marslen-Wilson, & Davis, 2003; Lignos, 2013 for reviews), morphological priming is a dominant methodology for investigating morphological processing. A general issue with morphological priming is that morphological relationships are confounded with semantic and phonological factors: i.e., *played* is phonologically and semantically related to *play*, in addition to hypothetical morphological relatedness (Marslen-Wilson, 2007, 184).

In the auditory domain, long-distance priming, where prime and target are separated by a number of intervening items, is used in an attempt to distinguish morphological priming from effects arising due to semantic and phonological similarity. Marslen-Wilson and Tyler (1998) found morphological priming in the absence of semantic priming at a distance of 12 intervening items. Kouider and Dupoux (2009) report facilitation for morphological priming at long distances (mean 72 intervening items), for which no facilitation for phonological and semantic priming is found. These morphological priming effects show a facilitation strength similar to repetition priming, leading Kouider and Dupoux (2009) to conclude that these morphological effects are independent of phonological and semantic priming.

However, there are explanations for the same type of finding that reject independent morphological processing. In the studies cited above, primes and targets are closely related both phonologically and semantically (*played* is used to prime *play*). As such, the apparent morphological effect can be analysed as an interaction effect between semantic and phonological similarity (see Feldman, 2000; Gonnerman, Seidenberg, & Andersen, 2007). These approaches are able to account for results like those reported in Kouider and Dupoux (2009): Even though phonology and semantics may not have independent effects at long distances, their interaction may still obtain at these long distances. Importantly, this interaction approach relies on the co-presence of shared semantics and phonology for any morphological effects to arise.

The research reported here explores morphological relatedness with *rhyme priming* (e.g., Monsell & Hirsh, 1998; Radeau, Segui, & Morais, 1994; Slowiaczek, McQueen, Soltano, & Lynch, 2000; Slowiaczek, Nusbaum, & Pisoni, 1987), which has been used to investigate phonological processing. Employing this technique to study morphology allows us to eliminate semantic confounds and to control for phonological relatedness in ways that are not possible with morphological priming. Rhyme priming refers to facilitation associated with the phonological notion of *rhyme* (shared vowel and coda consonants): e.g., faster responses to *bunch* after rhyming *lunch* than after non-rhyming *price*. As Norris, McQueen, and Cutler (2002) discuss, facilitatory rhyme priming

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effects seem to be the combination of two separate but additive effects: the presence or absence of rhyme and the amount of final phonological overlap. Slowiaczek et al. (2000) report that a shared *rhyme* (i.e., syllable nucleus + coda) produces significant facilitation, whereas non-rhyming phonological similarity produces only a weak priming effect (e.g., *ranch* only weakly facilitates *bunch*, c.f., Radeau, Morais, & Segui (1995), who found no effect in similar conditions).

Our use of rhyme priming is based on the following premise: If participants process *snow* as part of processing *snowed* because of their morphological relationship, then *snowed* should be facilitated by *dough* because *snow* and *dough* rhyme.

1.2. Experiment

Critical trials test the hypothesis that stems can be phonologically primed in morphologically complex words. Throughout the experiment, primes are semantically unrelated to targets. The experimental conditions each consist of four targets and two primes built around a regular English verb (see Table 1 for an example). The targets were chosen to study the main effect and control for phonological confounds. The BARE STEM target allows replication of previous findings concerning rhyme priming (e.g., *dough* → *snow* vs. *void* → *snow*). The PAST TENSE target consists of the crucial past tense forms (e.g., *dough* → *snowed* vs. *void* → *snowed*).

The remaining two target types control for phonological confounds. The first potential confound is word embedding, which arises due to the incremental nature of auditory speech processing. Responses to words may be influenced by the presence of other *phonologically* embedded words. Thus, for the PAST TENSE condition *snowed*, any facilitation could potentially be attributed to the phonological embedding of the stem *snow*, rather than its morphological structure. The EMBEDDED CONTROL condition consists of words which phonologically embed other words, but do not have concomitant morphological structure (e.g., *grove* embeds *grow*, but *grow* and *grove* are not morphologically related). Comparing the EMBEDDED CONTROL condition *grove* to the PAST TENSE condition *snowed* addresses the potential word embedding confound.

The second potential confound is partial rhyme. The RHYME prime and PAST TENSE target share a syllable nucleus, so any facilitation could be attributed to partial phonological overlap. The PAST TENSE RHYME CONTROL condition *code* provides a non-morphologically complex phonological control for the PAST TENSE condition (since *code* is not decomposable into real stem and affix). As the PAST TENSE RHYME CONTROL condition rhymes with the PAST TENSE condition, targets in these conditions always have the same partial phonological overlap with the RHYME condition prime. Therefore, comparison of these conditions excludes any facilitation which is due to a partial rhyme confound.

The PAST TENSE RHYME CONTROL condition also addresses the issue of segmentation effects for words with an "inflectional rhyme pattern" (IRP). An IRP is a word-final coronal consonant (/d, t, s, z/) that shows agreement in voice between the final coronal consonant and the preceding segment. Segmentation effects for stems and pseudo-stems in IRP words have been reported (e.g., Bozic, Tyler, Ives, Randall, & Marslen-Wilson, 2010; Post, Marslen-Wilson, Randall, & Tyler, 2008). However, facilitated processing of pseudo-stems (e.g., *co-* in *code*) due to rhyme priming may not facilitate responses to the IRP word, as pseudo-stem facilitation may interfere with word recognition. As such, if these segmentation effects are at play, we would not necessarily predict facilitation in responses in the PAST TENSE RHYME CONTROL condition.

In summary, theories with independent morphological processing predict that a rhyming prime *dough* will facilitate access to *snowed* via its morphological relationship with *snow*. Current theories without independent morphological processing would not be able to account for such an effect, since they rely on capturing morphological effects via interactions between semantic and phonological factors, and the semantic factors are absent in this experiment. Finally, if phonological overlap alone were responsible for facilitation effects, *dough* and *snowed* should behave like the phonological controls: that is, either identically to the EMBEDDED CONTROL condition *grove*, due to phonological embedding; or to the PAST TENSE CONTROL condition *code*, due to non-rhyming phonological overlap. Thus, to the extent that we find (increased) facilitation to morphologically complex (*snowed*) targets, this can be attributed to morphological processing independent of shared semantics and phonology.

Table 1
Examples of the experimental conditions (prime rhyme status is determined with respect to the Bare Stem target).

	Bare stem	Past tense	Past tense rhyme control	Embedded control
Non-Rhyme Prime	void	void	void	void
Rhyme Prime	dough	dough	dough	dough
Target	snow	snowed	code	grove (*grow* embedded)

2. Methods

2.1. Participants

34 native English speaking participants were recruited through the university subject pool. Participants were compensated with course credit.

2.2. Stimuli

Each critical item included a group of two primes and four targets built around a single regular verb. Stimuli consisted of 96 critical words (forming 16 critical items), 64 phonotactically licit non-words, and 32 filler words (see the online supplement for a list of items). One critical item was excluded from analysis, because it was determined not to satisfy our control criteria after the experiment had been run. Non-words and fillers did not rhyme with any other item in the experiment. As much as possible, stimuli were matched for SUBTLEX(US) frequency (Brysbaert & New, 2009). All stimuli were recorded by a male speaker of Standard American English.

2.3. Procedure

The experiment was run using Psychopy (Peirce, 2007) and responses were recorded using an Empirisoft Rotary Controller. Stimuli were presented to the participants binaurally through headphones in a continuous lexical decision task, with a random ISI between 400 and 600 ms. The ISI was measured from the end of the sound file or participant response, whichever was later.

Before the experiment, subjects performed 6 practice trials (4 word, 2 non-word). The experiment had 8 blocks with a break between blocks 4 and 5. In each block, participants saw one of the 8 conditions for each of the 16 critical items as well as all of the fillers. Fillers were repeated in each block. All subjects saw all conditions for all critical items. Participants were sequentially assigned to one of eight groups.

In order to maximise the distance between two tokens of the same target, the experiment was divided in half (blocks 1–4 and blocks 5–8). For the critical items, a Latin square design (across