Processing complex spoken words with obscured morphological identity and boundary: An auditory masked priming experiment

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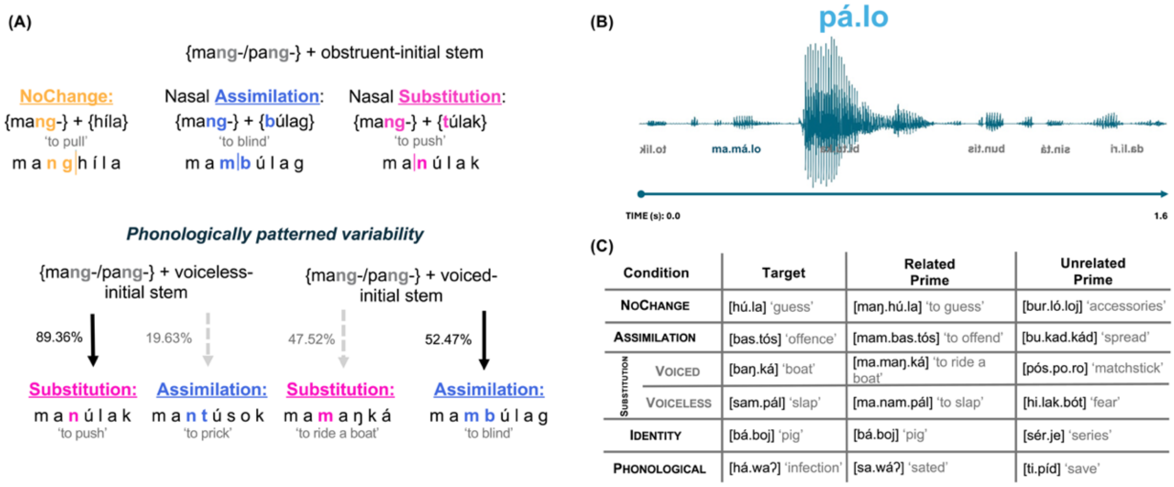
To comprehend speech, the auditory system must segment a continuous input stream at various levels (eg. sounds, words). Previous studies have shown that listeners also segment complex spoken words like *treatment* into their morphological units /ˈtriːt/+/mənt/, a process called morphological decomposition (eg. Creemers et al., 2023; Wilder et al., 2019). However, most evidence comes from cases with a clear morphological boundary between /stem/+/affix/, making decomposition more straightforward. It remains unclear whether decomposition is equally robust when the morphological boundary between /stem/+/affix/ is phonologically obscured, which could lead the parser to either delay morphological decomposition, or misidentify units (see Figure 1A for Language Background).

Here, we investigate whether complex words with obscured morphological identities and boundaries are segmented into morphemes during spoken word recognition in Tagalog. We used auditory masked priming with lexical decision to address this question, where the primes are compressed to 35% of their original duration and masked by being embedded into temporally reversed and compressed words (see Kouider & Dupoux, 2005 and Figure 1B for methodological details). Five conditions were included: [1] **NOCHANGE**: prefixed words without morphophonological alternation as primes and their stems as targets; [2] Nasal-**ASSIMILATION**: prefixed words with obscured prefix identity as primes and their stems as targets; [3] Nasal-**SUBSTITUTION**: prefixed words with obscured prefix and stem identities and obscured /prefix/+/stem/ boundary as primes and their unobscured stems as targets; [4] **IDENTITY**: the same monomorphemic words as primes and targets; and [5] **PHONOLOGICAL** Control: monomorphemic words that share the same second syllable as primes and targets. Within the **SUBSTITUTION** condition, there were two subconditions: [a] **VOICED**: nasal-substituted words with voiced-initial stems as primes; and [b] **VOICELESS**: nasal-substituted words with voiceless-initial stems as primes. Unrelated primes were real words with no morphological, phonological, or semantic relationship to the target stems (see Figure 1C for examples of primes and targets). 65 native Tagalog speakers were asked to judge whether the word they heard was a real word in their language or not.

Linear mixed-effects models revealed significant priming effects of similar magnitude for NOCHANGE (p = 0.0005), ASSIMILATION (p = 0.0005), SUBSTITUTION (p = 0.0010), and IDENTITY (p = p = 0.0076) conditions. No priming effects emerged for the PHONOLOGICAL (p = 0.9494) condition, suggesting that the priming effects obtained in the critical conditions were morphological in nature (see Figure 2A). Critically, we also found significant priming effects of similar magnitude for VOICED (p = 0.0080) and VOICELESS (p = 0.0173) subconditions (see Figure 2B). These findings show that complex spoken words are segmented into morphemes, consistent with spoken word recognition models that require decomposition (e.g., Marslen-Wilson et al., 1994; Balling & Baayen, 2012).

Crucially, Tagalog listeners decompose complex spoken words even when morpheme identity is obscured, and even when the obscuring of /prefix/+/stem/ boundary is variable. Our findings indicate that Tagalog listeners were not confused by ambiguous morphological boundaries (e.g., when hearing the input stream *mam,* the *m* can belong to the prefix in nasal-assimilated words like *ma**m**-búlag* or to the stem in nasal-substituted words like *ma-**m**angká*), as indicated by equivalent priming in the ASSIMILATION and SUBSTITUTION conditions and the VOICED and VOICELESS subconditions. Perhaps, Tagalog speakers are able to initiate decomposition upon hearing *ma-/pa-/na-* followed by a nasal sound, as these phonological sequences are reliable cues to morphological complexity. Overall, we provide clear evidence that automatic decomposition in speech comprehension remains robust and operational in the face of variable morphophonological alternations that obscure morphological boundaries.

Figure 1. General background of the study. **(A)** Language Background explaining nasal assimilation and nasal substitution. (B) Schematization of each trial, with example prime [mamalo] and target [palo]. In this Figure, the mask words (in gray) are backward, compressed, and smaller in print, to visually show that they were reversed, compressed, and reduced in amplitude; the word prime (in dark blue) is represented by being compressed and smaller in print to indicate primes were compressed and reduced in amplitude. (C) Examples of related and unrelated primes in each condition.



As shown in Figure 1A, in Tagalog, when velar-final prefixes are attached to obstruent-initial stems, two morphophonological alternations can surface: nasal **ASSIMILATION** and nasal **SUBSTITUTION** (see above for examples). Critically, whether **ASSIMILATION** or **SUBSTITUTION** will surface when velar-final prefixes are attached to obstruent-initial stems exhibits phonologically patterned variability: **ASSIMILATION** is more likely than **SUBSTITUTION** for voiceless-initial stems, while the opposite holds for voiced-initial stems (Zuraw, 2010). In spoken word recognition, this variability may add another level of processing difficulty when detecting the morphological boundary between prefix and stem as information unfolds over time. To illustrate, when Tagalog listeners hear the phonological input *mam*, the second nasal sound could belong to a prefix in nasal assimilation (e.g., *mam-búlag* 'to blind' from /maŋ/+/ búlag/) or a stem in nasal substitution (e.g., *ma-mangká* 'to ride a boat' from /maŋ/+/ baŋká/, which begins with the phonological sequence *ma-*) and in cases where the prefix *ma-*, which is different from *maŋ-*, is attached to an *m*-initial stem (*ma-mikrobyo* 'full of germs'). These instances could lead the parser to either delay morphological decomposition, or lead to errors.

Figure 2. The magnitude of priming effects was computed using the formula RTRelated Prime – RTUnrelated Prime. **(A)** Priming effects in ms by condition, illustrating that all morphologically related prime-target pairs evoked priming, in contrast with phonological overlap prime-target pairs. **(B)** Priming effects in ms for Voiced and Voiceless conditions. The point represents the means. The error bars represent the standard errors. The jitters represent individual datapoints.