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The effect of orthography on the visual processing of affixed words: Evidence from Bengali

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ABSTRACT

The view that morphologically complex words are decomposed into constituent morphemes during lexical access has gained traction in the psycholinguistic literature, which in turn has had significant implications for theories of lexical organisation and processing. Nevertheless, the bulk of evidence for how morphologically complex Indo-European words are accessed and stored is based on based on Latinate scripts, where the orthography tends to be sequential. In many languages however, it is not straightforward to determine the internal structure of the word from the script alone. To critically examine the morphological decomposition in the visual domain, we present results from a visual delayed priming study covering every possible combination of morphologically complex words (i.e. stem ~ prefixed, stem ~ suffixed, prefixed – prefixed, suffixed – suffixed, and prefixed ~ suffixed) in Bengali, a language rich with derivational morphology and orthographic complexity.

Results for configurations containing stems (stem ~ affixed) showed the only priming effects in the study; crucially, these findings depended heavily on whether the prime was a stem or affixed word. When the prime was a stem word, responses to both prefixed and suffixed targets were facilitated to a similar degree. When the primes consisted of affixed words (either prefixed or suffixed), they did not reliably prime stem targets. We also tested relationships between all affixed words and found no reliable priming effect for any combination. We argue that our results reflect not only modality-specific aspects of processing, but also asymmetries in the orthographic significance of phonological processes occurring at the stem-affix boundaries in Bengali.

1. Introduction

Languages in the Indo-European (IE) family are able to extend their vocabularies by adding affixes (e.g. prefixes, infixes, suffixes) to basic stems. Stems are often lexical words in their own right (although exceptions exist, e.g. {−mit} in *submit, permit,* which is a morpheme and a stem but not a word). A stem carries critical grammatical, phonological, and semantic information, all of which can be modified by derivational affixes (e.g. *pure* ~ *impure* ~ *purity* ~ *impurity*). While it is possible for the phonological shape of the stem to remain unchanged and 'convert' its word class with no overt affixation (i.e. conversion or zero-derivation, e.g., $bridge_N > bridge_V$ in English), adding overt affixes to a stem in order to create complex words is more typical. Empirical and experimental linguistic evidence has supported the claim that the internal structure of affixed words plays a key role in language comprehension (cf. Grainger & Beyersmann, 2017; Rastle & Davis, 2008; Taft & Forster, 1975): that is to say, whatever the status of the word (e.g. prefixed, infixed, suffixed), access to the stem is essential for successful word recognition.

In the psycholinguistic literature, reliable evidence for the decomposition of affixed words into affixes and stem comes from priming experiments, tasks in which participants' responses to pairs of related words are measured and compared (cf. Amenta & Crepaldi, 2012 for a comprehensive review). From Marslen-Wilson et al.'s (1994) seminal paper to more current work, results have generally agreed that morphologically related, semantically transparent words which share the same stem (e.g. *heal* ~ *healer*) facilitate responses to one another. This suggests that complex words undergo some level of decomposition into smaller morphemic units, namely the stem and the associated affix (es) (cf. Diependaele et al., 2009; Kazanina, 2011; although see Colé et al., 1989; Schreuder & Baayen, 1994; and Beyersmann et al., 2015 for different views). Nevertheless, some crucial questions about how

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derivationally complex words are stored in the mental lexicon remain unanswered, particularly in regard to the differences between affix types.

The cross-linguistic preference for suffixation over prefixation in Indo-European (IE) languages is widely known: most IE languages favour suffixes over prefixes[1] (cf. Sapir, 1921; Greenberg, 1957; Hall, 1988; Hawkins & Gilligan, 1988; Plank, 1988; Bybee et al., 1990). Reasons for this asymmetry have pointed toward listener preference for the position of the stem (Cutler et al., 1985), dissimilar grammaticalisation processes (Bybee et al., 1990; Greenberg, 1957), and phonological grouping (Himmelmann, 2014; Lahiri & Plank, 2010). Interestingly, the priming literature, regardless of paradigm or modality, generally reports stronger priming effects for associated pairs containing prefixed words (e.g. *pure* ~ *impure*)[2] (Feldman & Soltano, 1999; Giraudo & Voga, 2013; Grainger et al., 1991; Kazanina, 2011; Marslen-Wilson et al., 1994; Meunier & Segui, 2002; Wynne et al., 2021). Findings for configurations containing suffixed words (*pure* ~ *purity*) have revealed less evidence of facilitation, particularly when the target is presented visually (Comstock, 2018; Feldman & Soltano, 1999; Gonnerman & Andersen, 2000; Reid et al., 2003; Feldman et al., 2004; Crepaldi et al., 2016). Reasons for the asymmetry in findings have been linked to priming modality (i.e. masked, visual, auditory), length of time between prime and target presentation ('short-lag' vs. 'long-lag'), and length of stimuli display (interstimulus interval, or ISI) (cf. Smolka et al., 2009). While no single explanation for the asymmetrical behaviour of prefixes and suffixes has been accepted, it is apparent that the relationship between stems and suffixes is different from that between stems and prefixes.

An additional yet crucial aspect in this matter is orthography (cf. Perfetti & Liu, 2005). A written word in a sequential (e.g. Latinate) writing system is generally identifiable as a holistic unit, demarcated by spaces or punctuation marks. Even when prefixes and suffixes are added in these systems, the boundary between the stem and the affix tends to remain fairly transparent[3]: cf. the prefixed English words *regain* and *unhappy* (*re-gain, un-happy*) and the suffixed words *greenish* (*green-ish*) and *painting* (*paint-ing*). In many languages however, it is not straightforward to determine the internal structure of the word from the orthography alone: many writing systems exhibit significant "orthographic depth", a phrase first used by Liberman et al. (1980) to describe "the relative remoteness [of the orthography] from the phonetic representation" (p. 137). In writing systems such as abjads (e.g., Arabic), abugidas/alphasyllabaries (e.g., Bengali), or morphosyllabaries (e.g., Mandarin), affixation can involve more than a straightforward linear addition of a morpheme to a stem. The orthography of these systems can therefore exhibit significant non-linearity (or multilinearity) of morphemes, diacritics, grapheme alternations, visual complexity of characters, and/or ligatures (cf. Daniels & Share, 2018; Share, 2021).

Orthographic complexities in any given language can be tied to phonological processes such as re-syllabification, elision/deletion, and assimilation. When an affix attaches to a stem, the phonological shape of the stem hardly ever remains unchanged: for instance, a change in syllable structure can occur when an affix is added to a word, as in *rust* ~ *rusty* [rʌst.] ~ [rʌs.ti] where the coda consonant [t] of the stem is now re-syllabified as the onset of suffix *-y*. In English, the orthography remains relatively sequential despite the shift in syllable boundary: e.g., *rust* ~ *rusty*.[4] However in the abugida script of Bengali, the written shape of the affix (i.e. its grapheme) can be dictated by the phonological shape of the stem[5]: see, for example, the Bengali suffixed word *dam-i*$_{ADJ}$ 'expensive', which has undergone resyllabification during suffixation (Example 1). As in English *rust* ~ *rusty* [rʌst] ~ [rʌs.ti], the final coda consonant of the stem *dam*$_{N}$ 'price' becomes the onset of the suffix *-i*, [d̪ɑm] ~ [d̪ɑ.mi] (Example 1a). Critically however, unlike English *rust* ~ *rusty* [rʌst.] ~ [rʌs.ti], resyllabification alters how the suffix *-i* **is written** in Bengali (Example 1b).

Example 1: *dam* ~ *dam-i* resyllabification.

	stem	underlying suffix grapheme[6]	underlying form	surface form
1a)	d̪ɑm	-i	/[d̪ɑm.i]/	[d̪ɑ.mi]
1b)	দাম	ই	/দাম - ই/	দামি

[6] It is worth noting that this suffix in this word is never realised as ই when written; we only present this form for ease of analysis.

Instead of a simple linear attachment of the affix grapheme ই to the stem দাম, the affix is written as a diacritic on the stem: দামি (see Example 2).

Example 2. [d̪ɑm ~ d̪ɑm-i] orthography.

underlying form	surface form
/d̪ɑm-i/	[d̪ɑ.mi]
দাম - ই	দামি

This is due to systematic variations in how vowels are written in the language: if vowels are syllable initial, they are written with individual graphemes, e.g.[i.tʃɑ]: ('desire'). If there is a consonantal onset in the syllable (as in [d̪ɑ.mi]), however, they are written as vocalic diacritics.

Such orthographic alternations can also occur within stem morphemes after affixation: for example, stem vowel variation (e.g. English *metal* ~ *metallic,* [ˈmɛt.ɫ] ~ [mə.tæl.ɪk]) is often driven by affixation. In Bengali, where a vowel and a consonant can form a single grapheme, affixation can cause the written form of the word to undergo multiple orthographic changes. As an example, see the stem ~ suffixed pair [bʰut̪]$_{N}$ ~ [bʰoʊt̪ik]$_{ADJ}$ 'ghost ~ ghostly' (Example 3): here, the shape of the stem undergoes diphthongisation where the stem vowel of [bʰut̪] 'ghost' diphthongises from [u] > [oʊ] due to the attachment of the suffix *-ik*. Similar to [d̪ɑm] ~ [d̪ɑmi], the syllable boundary also shifts: [bʰut̪] ~ [bʰoʊ.t̪ik] (Example 3a). This has two consequences for the written form of the affixed word (see Example 3b and Example 4): first, the stem vowel changes, which is reflected in the written form of the stem [bʰut̪] ~ [bʰoʊt̪] Second, as in [d̪ɑm] ~ [d̪ɑmi] above, the affixed word resyllabifies and the onset of the suffix syllable is now a consonant ([bʰut̪] ~ [bʰoʊ.t̪ik]): the vowel now appears written as a diacritic inside the stem, as seen in Example 4:

[1] A reviewer has quite rightly pointed out that this does not apply universally; it has become increasingly clear that the suffixing preference is not equally strong for all morphological categories. For some categories (e.g. negation or personal crossreference), there may even be a cross-linguistic prefixing preference. We thank the reviewer for this important note.

[2] When referring to experimental configurations, the symbol ~ denotes priming combinations in both directions, e.g. *stem – PREFIX* and *prefix – STEM.*

[3] For the sake of clarity, we will refer to morphological boundaries as being 'transparent/opaque' and orthographic word parts as being "sequential/non-sequential".

[4] The orthographic string of an affixed word need not be identical to the original stem: the word *specified* can be decomposed into *specify* and *-ed*, where the shape of the stem changes because final <y > is usually written as <i > when followed by a vowel initial suffix in English. But while processes like word final devoicing may or may not be reflected in writing, the system is not random.

[5] While Bengali is entirely stem-based, stems are not the only conceivable basic unit of derivation cross-linguistically.

Example 3. *bhut* ~ *bhoutik* diphthongisation and resyllabification.

	underlying form 1			underlying form 2	surface form
3a)	bʰut̪	ik	/bʰut̪ -ik/	/ bʰoʊt̪-ik/	bʰoʊ.t̪-ik
3b)	ভূত	ইক	ভূত - ইক	ভৌত - ইক	ভৌতিক

Example 4. *bhoutik* ‘ghostly’.

underlying form 1	underlying form 2	surface form
/ bʰut̪-ik/	/ bʰoʊt̪-ik/	bʰoʊ.t̪ik
ভূত - ইক	ভৌত - ইক	ভৌতিক

The examples provided thus far have been restricted to suffixed words in Bengali, but orthographic complexities such as those illustrated above also occur in prefixed words.

For instance, in the prefixed Bengali word [aʤibon] ‘for eternity’(Example 5 below), attachment of the prefix *a* has no phonological effect on the stem: $[\text{ʤibon}]_{\text{N}}$ ~ $[\text{a-ʤibon}]_{\text{ADV}}$ ‘life ~ for eternity’; thus, there is no change to the orthography of either the stem or the affix.

Example 5. [ʤibon] ~ [aʤibon].

prefix	stem	underlying form	surface form
a	ʤi.bon	/a.ʤi.bon/	[a.ʤi.bon]
আ	জীবন	আ-জীবন	আজীবন

Orthographic complexity can be a direct result of phonological processes (e.g. assimilation, resyllabification) occurring during affixation: recall that asymmetries abound in the behaviour of how prefixes and suffixes attach to stems. For example, resyllabification between a consonant-final stem and a vowel-initial suffix (as above) is permitted more frequently in a stem-suffix combination than in a prefix-stem combination, cf. English *sanity* {san-ity} > [sæ.ni.ti] versus *unable* {un-able} > [ʌn.eɪbl], not *[ʌ.neɪbl]. This has ramifications for the stem: phonologically, suffixes adhere to the stem more than prefixes and thus the phonological shape of stems in prefixed words generally remains intact: [eɪ.bəl] ~ [ʌn.eɪ.bəl] vs. [seɪn] ~ [sæ.nɪ.ti]. Consequently, in Bengali, where orthographic changes such as clustering of consonants and vocalic diacritics occur as a result of these phonological processes, the written forms of the words can also be affected disproportionately.

The question we ask in this study is this: how do corresponding changes in orthography driven by phonological processes occurring on the boundaries of affixed words (such as those above) affect the processing of morphologically related words (e.g. *pure* ~ *impure*)? While recent work is starting to address the lack of cross-linguistic data (Boudelaa & Marslen-Wilson, 2005 for Arabic; Kim et al., 2015 for Korean; Kgolo & Eisenbeiss, 2015 for Setswana, Fiorentino et al., 2016 for Japanese, Farhy et al., 2018, Farhy & Veríssimo, 2019 for Hebrew; Yang et al., 2020, 2022 for Mandarin, and Cayado et al., 2023 for Tagolog), much of this evidence come from tasks which employ only one paradigm (masked priming). One particular limitation of the masked priming environment is the unavoidable effect of orthographic, phonological, and semantic overlap in morphologically related words (cf. Forster, 1998; Grainger & Ferrand, 1996; Rastle & Brysbaert, 2006): pairs such as *heal* ~ *healer* are not only similar in morphological structure, but also in sound, meaning, and written form.

This study presents data from a visual delayed priming study investigating the processing of morphologically complex Bengali words that complements existing results from a cross-modal study (Wynne et al., 2021). In our cross-modal study, we found distinct evidence of a processing asymmetry for affixed words in Bengali: in auditory-visual priming conditions, stems primed morphologically related prefixed words **more** than suffixed words, and prefixed words primed one another **more** than suffixed words primed one another. Here we compare visual processing across the same (full) range of stimuli of morphologically related stems and affixed words (stem ~ prefixed, stem ~ suffixed, prefixed ~ prefixed, suffixed ~ suffixed, and prefixed~ suffixed) in a delayed priming paradigm in order to investigate two things: 1) the effect of orthographic complexity on processing, and 2) the effect of removing the advantage provided by auditory primes in our previous cross-modal study. Our predictions draw on what is known about the visual processing of morphologically related affixed words, as well as the Bengali language itself. Consequently, we expect that any asymmetries in priming will not be solely attributable to orthographic alternations in the written forms of the language, but -crucially- on the phonological processes that are **driving the orthographic changes** occurring at boundaries of affixed words.

2. The prefix/suffix asymmetry

Across different priming paradigms and modalities, morphologically related words (*pure* ~ *purity*) have been shown to regularly speed response times to one another. This effect can be distinguished from effects of orthographic (*flow* ~ *flower*), phonological (*bear* ~ *bare*), or purely semantic (*lake* ~ *river*) relatedness (cf. Taft & Forster, 1975; Bradley, 1979). However, findings of this facilitation have not always shown equivalent results, particularly across different modalities: studies containing auditory stimuli (cross-modal or auditory-auditory) often report results that are incongruent to those reported by visual (i.e. masked or visual-visual) paradigms (cf. Crepaldi et al., 2016). Within the visual priming modality, the masked priming paradigm (Forster & Davis, 1984) has provided much of the existing evidence for how morphologically related items are visually processed. In masked priming studies where the degree of morphological overlap is manipulated (e.g. *pure* ~ *purity*), priming of morphologically related pairs is reliably present and both prefixed and suffixed words have elicited salient priming effects for related stem targets (i.e. affixed - stem, cf. Grainger et al., 1991; Taft, 2003; Rastle et al., 2004; Taft & Kougious, 2004; Longtin & Meunier, 2005).

This facilitation occurs in the other priming direction as well (i.e. stem - affixed), but signs of asymmetry arise. In configurations containing prefixes, stems reliably prime morphologically related prefixed targets. Forster and Azuma (2000) found that stems primed semantically transparent prefixed words in English (*happy* - *unhappy*) and Grainger et al. (1991) found priming for French stem - prefixed pairs, e.g., *nom* - *surnom* ‘name – last name’. Stem - prefixed pairs (e.g. рост - нарост, *rost* - *narost,* ‘growth - outgrowth’) in Russian also showed priming, even when they were pseudo-prefixed (e.g., тон - притон, *ton* - *priton,* ‘tone - den’) (Kazanina, 2011). Evidence for priming between words sharing identical prefixes is also robust (cf. Chateau et al., 2002, *dislike* - *disown*). Indeed, it appears that prefixed words elicit some of the strongest priming effects of all configurations in masked priming conditions, particularly when used as primes (Smolka et al., 2009; Kazanina, 2011; Kim et al., 2015; Beyersmann et al., 2016).

Evidence for configurations containing suffixes is less reliable: Kim et al. (2015) found that suffixed primes in Korean (e.g. 현실감, *hyeonsilgam*, ‘reality’) facilitated responses to stem targets (e.g. 현실, *hyeonsil*, ‘real’). and suffixed - stem pairs in English also primed for Rastle et al. (2000) and Kraut (2015). However, for stem - suffixed pairs in French (e.g. *mur* - *muret*, ‘wall - low wall’), Grainger et al. (1991) found no effect of priming. They also found no priming for suffixed ~ suffixed pairs in French (*mural* ~ *muret*), in contrast to Meunier & Segui (2002) findings for French suffixed ~ suffixed pairs (*tristement* ~ *tristesse*, ‘sadly ~ sadness’) and Smolka et al. (2009) in German (*mitkommen* ~ *kommen*, ‘come along ~ come’).

Repetition of stimuli in any form affects cognitive responses in specific ways: behaviorally, the effects of repetition priming can persist over long periods of time, even with added interference (cf. Henson et al., 2004). This persistence correlates heavily with the stimuli type (visual, auditory, etc.) as well as the time between the repeated items (i.e. “lag”).

This delay is normally achieved by either introducing a long interstimulus interval (ISI) or by increasing the number of intervening stimuli between prime and target. While the number of intervening stimuli can differ widely (e.g. from 5 items to 65 items) across the delayed priming literature, the absence of facilitatory effects for words related by pure semantic meaning (e.g. *horse* ∼ *cow*) and orthographic overlap has remained consistent (Rueckl & Aicher, 2008; Schuster & Lahiri, 2018; see also Darby & Lahiri, 2016 for zero-derivation words).

Morphological priming, on the other hand, can occur despite an increasing number of intervening items (cf. Murrell & Morton, 1974; Henderson, 1985; Bentin & Feldman, 1990; Drews & Zwitserlood, 1995; Marslen-Wilson & Tyler, 1998; Feldman, 2000; Bozic et al., 2007; Marslen-Wilson et al., 2008; Scharinger et al., 2009; Kouider & Dupoux, 2009; Gaston et al., 2021). Bentin and Feldman (1990) found that an increase in lag (from 0 to ∼15 items) reduced priming of word pairs that were associated both morphologically and semantically in Hebrew (sifriya- safran, '*library* - *librarian*'). Feldman and Larabee (2001) reported priming for suffixed - suffixed pairs (*payment* → *payable*) and stem - suffixed pairs (*pay* - *payment*) in English in visual long-lag (10 items) conditions, but prefixed primes elicited a weaker effect (significant only by participants) when paired with suffixed targets (e.g. *prepay* - *payment*). Gaston et al. (2021) report on a series of long-lag (average of 20 intervening items) priming experiments designed to investigate the representational status of "lexical stems and affixes" in memory; however, the study (conducted on Mechanical Turk) only tested relationships between suffixed words and related stems (e.g. *hero* ∼ *heroism*). The authors reported a weak priming effect for stem primes and suffixed targets (e.g. *hero* - *heroism*) and no priming for the reverse configuration of suffixed primes and stem targets (*heroism* - *hero*).

Thus, the scope of evidence for delayed processing of morphologically related words remains narrow, due perhaps to the fact that delayed priming tasks can be more complex to design, run, and analyse. However, if we want to particularly focus on the connections between morphologically related words without the influence of orthographic, semantic or phonological overlap, this seems to be the preferred paradigm for our purposes especially when we are investigating a language in which the orthography may be affected by phonological processes.

3. Complex words in Bengali

Before discussing the specific details of affixation in the language, we need to touch on the orthographic system of Bengali. The Bengali script is an alphasyllabic script, derived from the Brahmi writing system (cf. Bühler, 1898; Chatterji, 1926); it is written left to right, where consonantal graphemes have individual characters. Vowels in the Bengali writing system have two variants — when they are syllable-initial, they are written with individual graphemes; if there is a consonantal onset, the vowels are written as diacritics. The vowel diacritics can attach to the right, left, under or around the consonantal onset. Examples are given below of the syllables [kɑ], [ku], [ki], [ke] and [ko]. We have used the voiceless velar stop [k] to illustrate the various ways in which the vowel diacritics are employed.

Example 6.

	[ɑ]	[u]	[i]	[e]	[o]
vowel in isolation	আ	উ	ই	এ	ও
with consonantal onset [k] = ক	কা	কু	কি	কে	কো
	[kɑ]	[ku]	[ki]	[ke]	[ko]

The vowel diacritic for [ɑ] appears after the consonant, [u] comes below [k], [e] and [i] appear before the consonant and [o] circumscribes [k]. Moreover the vocalic diacritic can fluctuate across consonants. Thus, the shape of the vowel [u] can differ depending on the consonantal onset, sometimes changing the shape of the consonant (Example 6). The position and shape of the vowel diacritics may also differ depending on where the vowel appears in relation to the consonant-initial, pre-, and post-consonantal (cf. Example 7):

Example 7. Bengali vowel [u] with [r]:

<u>	<r>	<ur>	<ru>
উ	র	উর	রু
[u] as nucleus of a syllable	[r] on its own	pre-consonantal [u]	post-consonantal [u]

Within clusters, consonants can also vary in shape. Compare the individual segments <s t r > in Example 8 with the clusters involving the three letters in Example 9. Thus, when the two consonants appear as a cluster, the first consonant can be placed on top of the second, as in [rt̪] or the reverse [t̪r]. Bengali orthography includes three sibilants, <স শ ষ > all of which are pronounced as [ʃ] except in the context of a dental stop. The examples below are all based on the dental sibilant স which in isolation is pronouced as [ʃ] but in the clusters below, preceding a dental [t̪], it takes the articulation of [s].

Example 8. Bengali consonants.

r	ʃ/s	t̪
র	স	ত

Example 9. Bengali consonant clusters.

[st̪]	[t̪r]	[st̪r]
স্ত	ত্র	স্ত্র

A three-consonant cluster is the maximum that can occur in Bengali, beginning with a sibilant followed by an obstruent and a sonorant. Consonant cluster sequences also differ depending on sonority. Some letters are pronounced differently depending on whether they occur in a consonant cluster or not. As mentioned above, in isolation, the letter স will be pronounced as [ʃ]; however, word initially in a cluster, the sibilant is pronounced as [s]. Order matters in consonant clusters as well: in English, clusters such as [rt] and [tr] are just reversed sequences of [r] and [t]: *parting* vs. *patron.* Not so in Bengali, cf. Example 10 and compare the written form of the medial cluster [rd] to the cluster [dr].

Example 10. Bengali consonant clusters.

[pɔrd̪a] 'screen'	[bʰɔd̪ro] 'polite'
পর্দা	ভদ্র

The importance of orthographic representations (and consonant clusters in particular) becomes significant when we turn to affixation.

As discussed in Section 1, affixation is not always represented as a straightforward addition of an affix to a stem: in many abugida writing systems (such as Bengali, Malayalam, and Tamil), the non-linear arrangement of graphemes can result in the boundaries between stem and affix becoming less discernible. Furthermore, phonological processes that occur between stems and affixes are not always equal: for example, in words where the stem ends in a consonant and the suffix begins with a vowel (e.g. English *sane* ∼ *sanity* [səɪn] ∼ [sæ.ni.ti] vs. *own* [oʊn] ∼ *disown* [dɪs.oʊn],?[dɪ.soʊn]), resyllabification is permitted more in stem-suffix combinations than prefix-stem combinations.

In Bengali, morpho-phonological rules apply equally to both prefixed and suffixed domains. For example, Bengali allows resyllabification and assimilation to apply to both edges of an affixed word. In the prefixed word [ɔn-ɑd̪or]$_N$, 'disrespect', (Example 11) resyllabification causes the [n] of the prefix to become the onset of the first syllable of the stem: [ɑ.d̪or] ~ [ɔ.**nɑ**.d̪or]. The grapheme for [ɑ] in the stem আদর *ador*$_N$ 'love' is written as the individual character আ because its syllable has no onset: [ɑ.dor]. When prefixed however, the vocalic prefix gains a consonantal onset and becomes [nɑ], the orthographic form of which is না. Thus, the prefixed word undergoes phonological changes that are reflected in the orthography, effectively changing not only the sound of the stem and affix, but also the visual representation of these two morphemes.

Example 11. [ɔnɑd̪or] 'disrespect'.

underlying form	prefixed form
/ɔn-ɑ.d̪or/	[ɔ.nɑ.d̪or]
অন-আদর	অনাদর

In Section 1 (Example 1), we saw this same process occur in the suffixed word [d̪ɑmi] 'expensive', where resyllabification caused the final coda consonant of the stem [d̪ɑm] 'price' to become the onset of the suffix: [d̪ɑm] ~ [d̪ɑ.mi]. In these examples, we see that morpho-phonological rules apply equally to both prefixed and suffixed domains in the language, but the consequences of those rules can result in asymmetries at morpheme edges.

Assimilations in particular regularly affect stem and affix boundaries and there are consequences for the inherent asymmetry between suffixes and prefixes within the different types of assimilation. For example, the assimilation of features across stems and suffixes is more prevalent between a stem and a prefix (cf. English *bed-s* > *bed[z], cat-s* > *cap[s]*) than between a stem and a prefix (cf. *unpack* > [ʌn]*pack* and *un-popular* > [ʌn]*popular* (cf. Clements, 1985). In general, regressive assimilation is more frequent than progressive assimilation and consequently, suffixes will affect the stem more than prefixes. Recall the suffixed word [bʰout̪ik] 'ghostly' from Example 2 (reproduced below in Example 12). The vowel of the stem bhut 'ghost' diphthongises from [u] > [oʊ]: [bʰut̪] ~ [bʰoʊt̪ik] and the syllable boundary shifts, where [t̪] becomes the onset of the suffix syllable, triggering the use of the vocalic diacritic. Thus, suffixation is changing the shape of the stem both phonologically and orthographically.

Example 12. [bʰut̪] ~ [bʰoʊt̪ik] diphthongisation and resyllabification.

underlying form			
	Phonological:	vowel lowering and diphthongisation	resyllabification
	Orthographic:	stem shape change	affix shape change
/ bʰut̪-ik/ ভূত-ইক		/ bʰoʊt̪-ik/ ভৌত-ইক	[bʰoʊ.t̪ik] ভৌতিক

Where prefixes undergo assimilation or dissimilation, it is generally progressive with the result that the prefix (rather than the stem) changes shape. In the prefixed word [d̪uʃkrit̪i]$_N$, 'criminal' (Example 14), the underlying prefix is /d̪ur−/ as, in speech, the [r] assimilates to [ʃ] when followed by [k]. Thus, only the prefix changes shape (/d̪ur/ > [d̪uʃ]), with [ʃ] becoming the coda of the prefix. Orthographically, we see the [r] grapheme disappearing and the [ʃ] appearing as a diacritic on the consonantal onset [kr] of the stem:

Example 13. Assimilation in prefixation.

underlying form	prefixed form
/d̪ur-krit̪i/	d̪uʃ.kri.t̪i
দুর–কৃতি	দুষ্কৃতি

Originally the assimilation would have led to a retroflex sibilant [ʂ] (which is reflected in orthography), but the current language has only one sibilant [ʃ] irrespective of the writing system. Importantly, only the prefix is affected by the assimilation here and thus, the only orthographic change occurs at the affix-stem boundary.

The Bengali language has a complex set of rules reflecting phonological changes at stem edges in particular (as seen in Table A and B below for common changes that occur in prefixed words and suffixed words respectively). Consequently, phonological processes occurring at a morpheme edge can result in asymmetrical transformations of the phonological shape of the affix and/or the stem that in turn, may or may not be sequentially reflected in the orthography of the language.

Table A: Phonological and orthographic changes in Bengali prefixed words.

syllable structure	phonological effect	derived form	affix	stem	prefixed word	orthography	orthographic effect
(C)V - CVC	no change	a - dʒi.bon	আ	জীবন	a.dʒi.bon$_N$	আজীবন	no change
(C)VC - VC	resyllabification - the stem vowel now has an onset; in speech also there is resyllabification	ɔn - a.d̪or	অন	আদর	ɔ.na.d̪or$_N$	অনাদর	Stem shape changes
CVr - C([k], [ʧ])VC	in speech, the prefix is easily distinguishable despite the assimilation -thus the stem can easily be distinguished.	d̪ur - kriti	দুর	কৃতি	d̪uʃkriti$_N$	দুষ্কৃতি	prefix shape changes stem shape changes
CVr - C_1VC C1 = all other consonants	the phonological form of the stem remains untouched, as does the prefix; but see the orthography	d̪ur - mukʰ	দুর	মুখ	d̪ur.mukʰ$_{ADJ}$	দুর্মুখ	stem shape changes - the onset consonant gets the coda [r] of the prefix as a diacritic on top of it

Table B: Phonological and orthographic changes in Bengali suffixed words.

syllable structure	phonological effect	derived form	stem	affix	suffixed word surface form	orthography	orthographic effect
CV - CV	no change	bud̪ʰ:i - man	বুদ্ধি	মান	bud̪.d̪ʰ:i.man$_{\text{ADJ}}$	বুদ্ধিমান	no change
CVC - V(C)	resyllabification of stem final C; which affects pronunciation	d̪am- i	দাম	ই	d̪a.mi$_{\text{ADJ}}$	দামি	Stem shape changes
(CV)CV - V(CV) > (CV)C - V(CV) > (CV).CV.CV	Stem shape changes - vowel elision: final vowel of stem deletes, and the medial C becomes the onset of the vowel of the suffix.	ʃik.kʰɑ - it̪o	শিক্ষা	ইত	ʃik.kʰi.t̪o$_{\text{ADJ}}$	শিক্ষিত	Stem shape changes
CVC - VC > CVC - VC	Stem shape changes affecting pronunciation: (stem vowel diphthongises)	bʰut̪ - ik	ভূত	ইক	bʰoʊ.t̪ik$_{\text{ADJ}}$	ভৌতিক	Stem shape changes
CV r - C [cor] V > gemination	assimilation leading to gemination of stem coda C; the stem pronunciation changes	proʧur - ʤo	প্রচুর	য	prɑ.ʧuʤ.ʤo$_{\text{N}}$	প্রাচুর্য	Stem shape changes

4. Predictions

Having addressed general priming behaviour for visually presented Bengali affixed words and their stems, we turn to the predictions for our study. In Wynne et al. (2021; cross-modal), we tested for priming between all configurations of stem and affixed words in Bengali:

Table 2**.** Configurations tested in Wynne et al. (2021).

Configuration	Bengali		English gloss
Stem ~ Prefixed	ɑdor ~ ɔn-ɑdor	আদর ~ অনাদর	*respect ~ disrespect*
Stem ~ Suffixed	lobʰ ~ lobʰ-onio	লোভ ~ লোভনীয়	*greed ~ covetable*
Prefixed ~ Prefixed	duʃ-kriti ~ ʃu-kriti	দুষ্কৃতি ~ সুকৃতি	*criminal ~ righteousness*
Suffixed ~ Suffixed	bʰagːo-hin ~ bʰagːo-ban	ভাগ্যহীন ~ ভাগ্যবান	*luckless ~ lucky*
Prefixed ~ Suffixed	nir-loʤːo ~ loʤː-ito	নির্লজ্জ ~ লজ্জিত	*shameless ~ ashamed*

Our study yielded two somewhat incongruent findings to those in Marslen-Wilson et al. (1994)'s study: first, all configurations in Bengali (including suffixed-suffixed pairs) primed, and second, some configurations primed **more** than others. Morphologically related prefixed – prefixed pairs primed more than suffixed – suffixed pairs, and stem primes elicited more priming for prefixed targets than for suffixed targets.

In this study, we are focussed on the visual processing of derivationally complex words and their stems in Bengali. We did this by systematically testing for priming between pairs of morphologically related words ([lobʰ]$_{\text{N}}$ ~ [lobʰ-onio]$_{\text{ADJ}}$ 'greed ~ covetable') in all stem and affixed word pair configurations (i.e. stem ~ prefixed, stem ~ suffixed, prefixed ~ prefixed, suffixed ~ suffixed, and prefixed ~ suffixed) (see Table 2 above; Fig. 1).

To ensure that we were tapping into morphology whilst keeping aside the effects of orthographic, phonological and/or semantic overlap, we chose to present these stimuli in a visual delayed paradigm with an average lag of 7 items separating word pairs. To the best of our knowledge, no study has presented findings from all configurations in a visual delayed priming configuration in any language. Thus, our predictions will be based on what we know about the language as well as the priming literature. To underline, we are concerned with the decomposition of the visual complex words into their distinct components and how phonological (and thus consequential orthographic) processes affect stem access. The predictions are structured similarly to the organisation of the study, which first examines the relationship between Bengali morphologically related words and their stems (e.g. stem ~ prefixed/ suffixed), and then affixed words (prefixed/suffixed).

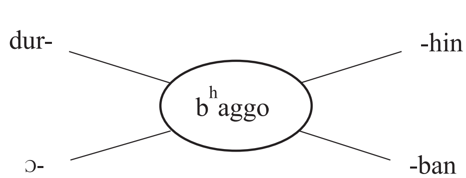

Fig. 1. Combinatorial Possibilities in Bengali for stem bʰaggo 'luck'.

Our intention in the first set of experiments (stem ~ affixed) was to understand the relationships between stems and their affixes in processing, keeping in mind the possibility of different types of phonological effects occurring at the stem edges. In cross modal (auditory-visual) priming experiments containing Bengali stem ~ affixed configurations, we found that decomposition was harder when the target was affixed (cf. Wynne et al., 2021). There was also an asymmetry in the degree of priming for the different types of visual targets (i.e. prefixed vs. suffixed). This suggests two things: when an affixed target word is presented visually, decomposition relies not only on information offered in the prime word, but also on orthographic information in the target word. In our cross-modal experiments, clues to phonological boundaries may be provided in the auditory prime stimulus that would be absent in a prime that was only presented visually. Thus, our first prediction is that we expect visually presented affixed words to be harder to decompose when the comprehender is relying only upon information in the written word.

Second, tin Sections 1 and 1.4, we saw that phonological alternations can result in asymmetrical consequences on the written form of the word in Bengali, cf. [d̪ʰɔrmo]$_{\text{N}}$, [ɔ- d̪ʰɔrmo]$_{\text{N}}$, [d̪ʰɑrm-ik]$_{\text{ADJ}}$ in Example 14 below.

Example 14: Bengali affixation.

	stem	suffixed form	prefixed form
	[d̪ʰɔr.mo]	[d̪ʰɑr.m-ik]	[ɔ-dʰɔr.mo]
Underlying Form	ধর্ম	ধর্ম-ইক	অ-ধর্ম
Surface Form	ধর্ম	ধার্মিক	অধর্ম

The suffixed form [d̪ʰɑrmik] 'righteous' is underlyingly /d̪ʰɔr.m**o**.-ik/, from stem /d̪ʰɔrmo/ 'religion' and suffix [−ik]. Bengali disallows a sequence of two vowels within a word, thus the stem final vowel [o] in stem [d̪ʰɔrmo] deletes and the consonant [m] becomes the onset of the vowel of the suffix: /d̪ʰɔr.m**o** - ik/ > [d̪ʰɑr.mik]. Hence, the stem /d̪ʰɔrmo/ has undergone phonological changes that have resulted in the

Table 1
Morphologically Related pairs.

	Ex 1: Stem ↔ Prefix	Ex 2: Stem ↔ Suffix	Ex 3: Prefix → Prefix	Ex 4: Suffix → Suffix	Ex 5: Prefix ↔ Suffix
Prime	আদর [ɑd̪or]$_{N}$ ‘fondness’	দাম [d̪ɑm]$_{N}$ ‘cost’	দুষ্কৃতি [d̪uʃ-krit̪i]$_{N}$ ‘misdeed’	ভাগ্যবান [bʰɑgːoban]$_{ADJ}$ ‘fortunate’	নির্লজ্জ [nir-lɔdʒːo]$_{N}$ ‘immodesty’
Target	অনাদর [ɔn-ɑd̪or]$_{N}$ ‘disrespect’	দামি [dɑm-i]$_{ADJ}$ ‘costly’	সুকৃতি [ʃu-krit̪i]$_{N}$ ‘good deed’	ভাগ্যহীন [bʰɑgːo-hin]$_{ADJ}$ ‘unfortunate’	লজ্জিত [lodʒː-it̪o]$_{ADJ}$ ‘embarrassed’

Table 2
Experimental Conditions (Examples from Stem → Suffixed configuration).

	Morphological	Semantic	Form
Related Prime	দাম [dɑm]$_{N}$ ‘cost’	নিদ্রা [nid̪rɑ]$_{N}$ ‘sleep’	লেখা [lekʰɑ]$_{N}$ ‘writing’
Unrelated Prime	মাথা [mɑt̪ʰɑ]$_{N}$ ‘head’	চান [ʧɑn]$_{N}$ ‘bath/shower'	তিমি [t̪imi]$_{N}$ ‘whale’
Target	দামি [dɑm-i]$_{ADJ}$ ‘costly’	ঘুমন্ত [gʰumont̪o]$_{ADJ}$ ‘sleepy’	লেপন [lepon]$_{N}$ ‘coating’

morphological boundary between the stem and the affix becoming **less transparent**. Once the stem final vowel [o] of [d̪ʰɔrmo] deletes before the suffix vowel of [ik], not only has the stem shape changed, but the resyllabification of resulting stem final consonant [m] to the [ik], has triggered the use of the vocalic diacritic which now appears written inside the stem word. Thus, the final syllable of [d̪ʰɑrmik], has the [i] written as a diacritic on the new onset [m]. The prefixed form [ɔ-d̪ʰɔrmo] ‘unrighteousness’, on the other hand, undergoes no phonological changes, nor does the orthography change. Thus, based on what is known about the asymmetry in the effects of phonological processes that occur during prefixation versus suffixation, we predict an asymmetry in the priming effects between prefixed and suffixed words.

Our second group of experiments examines configurations in which both the primes and targets are affixed words that share the same stem (i.e. prefixed ~ prefixed, suffixed ~ suffixed, prefixed ~ suffixed). In all of these configurations, any advantage of (isolated) stem presentation is absent, and decomposition must occur in **both** prime and target in order to access the stem, e.g. [bʰɑgːo-ban]$_{ADJ}$ ‘lucky’ ~ [bʰɑgːo-hin]$_{ADJ}$ ‘luckless’. Recall our predictions for visually presented affixed words in Section 1.5.2 above: not only do we predict that affixed words will be harder to decompose when no auditory information is provided, but we also predict an asymmetry in the ease of decomposition due to

Table 3
Mean Item Characteristics (Morphological).

	Average word frequency	Average phoneme length
Stems	548.9	4.9
Affixed Words	53.0	7.3
Suffixed Words	80.6	7.3
Prefixed Words	25.8	7.3
Exp 1 (Stem ~ Prefixed)	37.3	7.6
Exp 2 (Stem ~ Suffixed)	143.9	6.7
Exp 3 (Prefixed ~ Prefixed)	15.3	7.5
Exp 4 (Suffixed ~ Suffixed)	51.1	7.6
Exp 5 (Prefixed ~ Suffixed)	76.2	6.6

asymmetrical phonological (and therefore orthographic) alternations that occur during affixation. Returning to our triplets [d̪ʰɔrmo], [ɔ-d̪ʰɔrmo], [d̪ʰɑrm-ik] (Example 15), the lack of symmetry between prefixed [ɔ-d̪ʰɔrmo], and suffixed [d̪ʰɑrm-ik] is evident:

Example 15. [ɔ-d̪ʰɔrmo] ~ [d̪ʰɑrm-ik]; prefix [ɔ-], suffix [−ik].

stem	prefixed form	suffixed form
[d̪ʰɔrmo]	[ɔ-dʰɔr.mo]	[dʰɑr.mik]
Phonological change:	none	stem final vowel deletion before vowel initial suffix: *stem shape changes*
Orthographic change:	none	resyllabification - suffix vowel becomes a diacritic: *affix shape changes*
Underlying Form:	অ-ধর্ম	ধর্ম-ইক
Surface Form:	অধর্ম	ধার্মিক

On the basis of this information, we again expect an asymmetry in priming for prefixed and suffixed words: if stems are relatively untouched by the phonological processes occurring across prefix-stem boundaries, then it follows that prefixed words should prime related prefixed words more than suffixed words prime related suffixed words. In our cross-modal experiments (2021), all configurations primed and, crucially, prefixed ~ prefixed pairs primed more than suffixed ~ suffixed pairs.

5. The present study

5.1. Methods and design

5.1.1. Stimuli

Using visual delayed lexical decision tasks, we tested for priming in all configurations for Bengali stem words and affixed words (stem ~ prefixed, stem ~ suffixed, prefixed ~ prefixed, suffixed ~ suffixed, prefixed ~ suffixed): this resulted in five experiments. Our critical comparison was between morphologically related and unrelated pairs of Bengali words (*dam ~ dam-i*, ‘cost ~ costly’) (Table 1).

Alongside this condition, we also tested for words related semantically ([nid̪ra] ~ [gʰum-ont̪o], ‘sleep ~ drowsy’), or orthographically ([lekʰa] ~ [lep-on], ‘writing ~ coating’) (see Table 2).

The test (morphologically related) stimuli were the same as those in Wynne et al. (2021). Experiments 1, 2 and 5 used 16 test items, and Experiments 3 and 4 used 32 test items (see Appendix B for full lists). At the time of the original design, access to a corpus of Bengali word frequencies was not available. All affixes used in the test stimuli were highly productive and all items were rated by an independent rater as highly familiar. We have since been able to gather frequency information from a modern Bengali corpus of 4 million words developed under the Govt. of India TDIL (Technology Development for Indian Language) project (cf. Dash, 2000, 2004; Dash & Chaudhuri, 2001). Mean item

Table 4
Examples of nonword stimuli.

	Suffixed → Stem [Morph]	Prefixed → Stem [Morph]	Prefixed → Suffixed [Morph]	Stem → Suffixed [Sem]	Stem → Suffixed [Form]
Nonword Prime	*klant̪-amo ক্লান্তামো	*ʃu-gen শূগেন	*ɔ-bʰogan অভোগান	*gaʤu গাজু	*ʃem শেম
Nonword Target	*klant̪a ক্লান্তা	*gen গেন	*bhɔgn-ati ভগ্নেতি	*alpo-dar আল্লোদার	*ʃem-u শেমু

Table 5
Example Design of Experiments 1a (Stem → Prefixed) and 1b (Prefixed → Stem).

	Stem → Prefixed		**Prefixed → Stem**	
	List 1	**List 2**	**List 1**	**List 2**
	Related	**Unrelated**	**Related**	**Unrelated**
Prime	**stem** আদর 'fondness'	**stem** দীর্ঘ 'large'	**prefixed word** অনাদর 'disrespect'	**prefixed word** নিঃশব্দ 'silent'
Target	**prefixed word** অনাদর 'disrespect'		**stem** আদর 'fondness'	

characteristics (average word frequency and average phoneme length) are given in Table 3.

Several things become immediately clear: first, Bengali stems have higher frequencies than affixed words. Second, average word frequencies for prefixed words are noticeably lower than those for suffixed words. This is in line with asymmetries in the language: in a survey of affixed words in the TDIL corpus, suffixed words (84.82 %) significantly outnumbered prefixed words (10.04 %). It is, however, important to note that any measurement of word frequency in Bengali will be affected by a lack of distinct word boundaries due to substantial orthographic inconsistences in the written language (for a detailed discussion of orthographic variations in Bengali, see Dash, 2007).

Our five experiments and their results are presented in two groups: 1) configurations examining the relationship between affixed words and stems (Experiments 1 and 2), and 2) configurations containing affixed words as both primes and targets (Experiments 3, 4 and 5). Within all of these comparisons, the degree of priming across experiments and configurations (e.g. stem → affixed vs. affixed → stem) was also examined and will be reported in the results for each experiment group. The following section presents the experimental design in detail.

5.1.2. Design

All lexical decision tasks followed the same design: participants had to make a lexical decision response to every stimulus by deciding whether it was an extant word in Bengali or not. Nonword stimuli were constructed to match the degree of complexity and overlap of the experimental condition, e.g. *[klɑnt̪ɑmo] → *[klɑnt̪ɑ] for a suffixed → stem 'related' nonword pair (see Table 4 for examples of nonword stimuli across different conditions).

All lexical decision tasks followed the same design. All stimuli were displayed for 1200 ms. Pairs were presented with a lag of 5–7 items between. The inter-trial-interval was 2500 ms and after every 16 items participants were told to take a brief break. Due to the large number of trials (576 trials total in each list), the experiment was split into three parts of approximately ten minutes each to allow for a longer break in between each part.

In Experiments 1, 2 and 3 (Stem ~ Prefixed/ Stem ~ Suffixed/ Prefixed ~ Suffixed), each stimulus served both as target and prime; the experiments were thus divided into four separate lists to avoid repetition of any of the target stems (see Table 5). Presentation of stimuli within these lists was pseudorandomised and the presentation of related versus unrelated primes in test conditions was counterbalanced across the lists. Importantly, stimuli in Experiments 1, 2 and 5 were combined together in presentation: e.g. a participant would receive intermixed stimuli from Stem → Prefixed, Stem → Suffixed, and Suffixed → Prefixed configurations. We did this to avoid any list context or repetition effects. (See Tables 6 and 7.)

Experiments 3 and 4 (Prefixed ~ Prefixed/ Suffixed ~ Suffixed) consisted of primes and targets of the same degree of complexity, thus removing the need for each item to serve as both prime and target. Experiments 3 and 4 were also combined together in presentation so that participants would receive variation in the types of words they saw. In all other respects, the procedure used was identical to Experiments 1, 2 and 5.

5.2. Participants

160 Bengali native speakers (average age 20) participated in the study ($N = 32$ in each experiment). Participants were undergraduate students at Jadavpur University Kolkata, Satyapriya Roy College of Education Kolkata, and JRSET College of Education Nadia, India. The study was approved by all institutions' research ethics committees. Subjects had no hearing impairments and normal or corrected-to-normal vision. Each participant gave their informed consent for participation and was reimbursed appropriately.

Table 6
Mean reaction times in ms and error rates for stem → prefixed configurations (* denotes a significant effect).

	Morph Pairs *ador → onador* 'love → disrespect'			**Sem Pairs** *shahosh → nirb^haya* 'courage → fear'			**Form Pairs** *basha → abashara* 'home → leisure'		
	RT			**RT**			**RT**		
	R	**UR**	**Effect**	**R**	**UR**	**Effect**	**R**	**UR**	**Effect**
Stem → Prefixed	622	679	57*	662	667	NS	648	638	NS
	SE			**SE**			**SE**		
	6.2	7.4		6.9	7.6		7.8	8.3	

Table 7
Mean reaction times in ms and error rates for stem ~ prefixed configurations (* denotes a significant effect).

	Morph Pairs *onador → ador* 'disrespect → love'			**Sem Pairs** *nirb^haya → shahosh* 'fear → courage'			**Form Pairs** *abashara → basha* 'leisure → home'		
	RT			**RT**			**RT**		
	R	**UR**	**Effect**	**R**	**UR**	**Effect**	**R**	**UR**	**Effect**
Prefixed → Stem	646	649	NS	673	685	NS	687	721	NS
	SE			**SE**			**SE**		
	6.7	7.8		7.4	9.1		8.6	8.9	

5.3. Procedure

The experiment took place in quiet rooms at each institution. Despite the lack of auditory stimuli, participants were instructed to wear headphones to minimise distraction by outside noise or other subjects' responses. Participants were assigned to one of the experimental lists outlined above and thus only saw each target once. The experimental environment consisted of the experimental hardware, a MacBook Pro running OS X from which the XMOD data gathering software (Reetz & Kleinmann, 2003) was operated, push button boxes to give and record responses, and a video projector to present the stimuli on a screen.

Each stimulus was presented in Bengali script in font size 96 and remained on the projector screen for 1200 ms. Participants were instructed to respond to every item on the screen by deciding whether it was an extant word in Bengali or not, using the push button box provided. 'Yes' responses were made by the participant's dominant thumb. Participants had up to 2500 msec to make a lexical decision. At the beginning of each testing session, participants were provided with oral instructions in Bengali and were given the opportunity to ask clarification questions before a ten-item practice task was conducted. Participants participated in three practice runs consisting of 10 practice items. Each session lasted approximately 45 min.

5.4. Analyses

The data, analysis code, and materials to reproduce the analyses and figures are available on OSF (https://osf.io/erkpu/?view_only=314608a3fa114b36a19b31e4db231b24). All files were cleaned using the same procedure: any data points beyond two standard deviations from subject means were counted as outliers and removed. Incorrect responses were also removed, and corresponding prime-target pairs for the incorrect item were also removed. Reaction time was measured from the onset of stimulus display. Analyses looked at priming effects of the three types (Morphological, Semantic, Form) of related words in comparison to unrelated control primes. Factors under investigation were coded as Condition (Morphological, Semantic, Form) and Prime Type (Related/Unrelated). In addition to looking at priming effects within each Configuration, we also compared the degree of priming across Configurations: factors in these analyses included Word Complexity (Stem/Affix), Direction of Priming (e.g. stem → prefixed/ prefixed → stem), and Affix Type where applicable (Suffix/Prefix).

Using the R Statistical Software (R Core Team, 2015) and the 'lme4' package (Bates et al., 2015), statistical analyses were performed by fitting a linear mixed-effects model to reaction times. We chose to follow the recommendations by Matuschek et al. (2017) to determine the random effect structure, that is to select the model where the complexity of the random effect structure is supported by the dataset. Starting with the full random effect structure, a step-wise reduction approach was used. A likelihood ratio test (LRT) is used to test whether reducing the random effect harms the model fit. $\alpha_{LRT} = 0.2$ is used which gives more weight to more complex models (Matuschek et al., 2017). Subjects and items were treated as random factors. All factors, where appropriate, were treatment coded. Following Barr et al. (2013) and Matuschek et al. (2017), the random effect structure was kept maximal. Following Baayen et al. (2008), t-values and standard errors are reported for significance of effect in these models. A number of diagnostics were carried out for each analysis to check goodness-of-fit of the model to the data: these included tests for normality of residuals, absence of collinearity, and independence. For normality of residuals, scatterplots, histograms, and quantile-quantile (QQ) plots were visually inspected with respect to the presence or absence of patterns of heteroscedasticity. If the diagnostics discussed above identified a heteroscedastic distribution of data, steps were taken to ratify this: profile log-likelihoods of reaction times were generated via a Box-Cox power transformation from the "Car" package (Fox et al., 2012). When the fixed effect Prime Type (Related/Unrelated) or an interaction with it was significant, this was followed up by a post-hoc test using the *emmeans* package (Lenth, 2023) in R. Error rates were analysed proportionally using a generalised linear model (GLM) with a binomial distribution (link = logit). For each experiment, we report the significant error rates for each Condition, Prime Type and (if appropriate), Configuration.

Table 8
Reaction times and effect sizes for stem ~ prefixed morphologically related pairs.

Configuration:	Morph Pairs *ador ~ onador* 'love ~ disrespect'			
	RT in ms (SE)			
	R	UR	Effect	Effect size (Hedges *g* with 95 % CI)
Stem → Prefixed	622 (6.2)	679 (7.4)	57*	0.42 [0.27, 0.56]
Prefixed → Stem	646 (6.7)	649 (7.8)	NS	0.02 [−0.12, 0.16]

6. Results

6.1. Priming configurations containing stems

6.1.1. Experiment 1a and 1b: Stem ~ prefix

Experiment 1 present results for the priming configuration containing stems and prefixes: Experiment 1a utilised stem words as primes (e.g. [ɑd̪or] → [ɔn- ɑd̪or], 'love → disrespect') and Experiment 1b utilised prefixed words as primes [ɔn- ɑd̪or] → [ɑd̪or], 'disrespect → love').

6.1.1.1. Experiment 1a: stem → prefixed priming. For the stem → prefixed configuration, outlier removal resulted in a loss of 1411 data points (23 % of the total data). After nonword removal, the optimal model (*N* = 2311) to converge contained an interaction between the fixed effects Condition and Prime Type, by-subject and by-item random intercepts, and by-item random slopes for Prime Type.[6] This model appeared homoscedastic when inspected visually and significant differences were found when compared to a model where the interaction between the fixed effects was removed[7] ($\chi^2(2) = 10.50$, $p = 0.005$*). There was a significant interaction between Prime Type and Condition, but this effect was only observable in the pairwise comparisons in the Morphological condition (Est. = 43.76, SE = 11.3, $t = 3.88$): seeing a stem facilitated faster responses (57 ms) to a morphologically related prefixed word than an unrelated word prime. Stem words did not prime semantically related prefixed words (Est. = 3.64, SE = 10.7, $t = 0.33$), nor did stems prime orthographically related prefixed words (Est. = −4.69, SE = 12.0, $t = -0.39$).

Error rates revealed that Prime Type (Related/Unrelated) had an effect: unrelated words induced significantly more ($\chi^2(1) = 9.6$, $p = 0.002$*) errors than related (8.7 % and 5.6 % respectively). Error rates were similar across all three Conditions (semantic, form and morphological): ($\chi^2(2) = 0.379$, $p = 0.83$). There was no interaction between Prime Type and Condition.

6.1.1.2. Experiment 1b: prefixed → stem priming. For the prefixed → stem configuration, outlier removal resulted in a loss of 1518 data points, (24.7 % of the total data). After nonword removal, the optimal model (*N* = 2093) to converge was a model containing the fixed effect Prime Type (Related/Unrelated), by-subject and by-item random

[6] lmer(ReacTime~RELATED*CONDITION+ (1| SJ) + (1 + RELATED| Target))

[7] lmer(ReacTime~RELATED+CONDITION+ (1| SJ) + (1 + RELATED| Target))

Table 9
Mean reaction times in ms and error rates for stem → suffixed configurations (* denotes a significant effect).

Configuration:	Morph Pairs *dam → dami* 'cost → costly'			Sem Pairs *nidra → gʰumonto* 'sleep → sleepy'			Form Pairs *lekʰa → lepon* 'note → coating'		
	RT			RT			RT		
	R	UR		R	UR	Effect	R	UR	Effect
Stem → Suffixed	611	646	35*	650	651	NS	661	666	NS
	SE			SE			SE		
	5.4	6.3		6.2	6.0		7.9	7.9	

Table 10
Mean reaction times in ms and error rates for suffixed → stem configurations (* denotes a significant effect).

Configuration:	Morph Pairs *dami → dam* 'costly → cost'			Sem Pairs *gʰumonto → nidra* 'sleepy → sleep'			Form Pairs *lepon→ lekʰa* 'note' → 'coating'		
	RT			RT			RT		
	R	UR	Effect	R	UR	Effect	R	UR	Effect
Suffixed → Stem	642	645	NS	667	700	NS	646	697	NS
	SE			SE			SE		
	6.5	6.9		6.6	8.6		7.6	9.2	

Table 11
Reaction times and effect sizes (Hedges *g* with 95 % CI).

Configuration:	Morph Pairs *dam ~ dami* 'cost ~ costly'			
	RT (SE)			
	R	UR	Effect	Effect size (Hedges *g* with 95 % CI)
Stem → Suffixed	612 (5.4)	647 (6.3)	35*	0.27 [0.14 0.40]
Suffixed → Stem	642 (6.5)	645 (6.9)	NS	0.04 [−0.09 0.17]

Table 12
Reaction times (in ms) for stem ~ affixed configurations (* denotes a significant effect).

	R	UR	effect		R	UR	effect
Stem → Affixed				Affixed → Stem			
Stem → Prefixed	622	679	53*	**Prefixed → Stem**	646	649	NS
Stem → Suffixed	612	647	35*	**Suffixed → Stem**	642	645	NS

intercepts, by-subject random slopes for Condition, and by-item random slopes for Prime Type.[8] It also contained log-transformed[9] values for Reaction Time: profile log-likelihoods of reaction times were generated via a Box-Cox transformation (λ = −0.79). A model containing an interaction[10] between the fixed effects Prime Type and Condition showed no significant difference ($\chi^2(2)$ =3.65, p = 0.16) to one in which the interaction was removed.[11] Furthermore, removal of the fixed effect

[8] lmer(logReacTime~Related+(1 + Cond|SJ) + (1 + Related|TARGET_LABEL), data = d)
[9] RT was log-transformed in this analysis due to distinct skewing in the visual inspection of residuals. Although optimum λ = −0.80, the lower confidence limit exceeded −1.
[10] lmer(logReacTime~Related*Condition+(1|SJ) + (1|TARGET_LABEL), data = d)
[11] lmer(logReacTime~Related+Condition+(1|SJ) + (1|TARGET_LABEL), data = d)

Table 13
Effect sizes for all stem ~ affixed configurations as measured by Hedges' *g* with 95 % CI.

Effect Size		Effect Size	
Stem → Affixed		**Affixed → Stem**	
Stem → Prefixed	0.42 [0.27, 0.56]	**Prefixed → Stem**	0.02 [−0.12, 0.16]
Stem → Suffixed	0.27 [0.14, 0.40]	**Suffixed → Stem**	0.04 [−0.09, 0.17]

Condition[12] did not result in a significant difference when compared to a model containing the fixed effect: ($\chi^2(7)$ =8.45, p = 0.29). Removal of the fixed effect Prime Type[13] (and thus comparison to the null model) resulted a significant difference ($\chi^2(1)$ =4.97, p = 0.03*).

Error rates revealed that Prime Type (Related/Unrelated) had a significant effect ($\chi^2(1)$ =6.37, p = 0.01*) on error rates: unrelated word pairs resulted in significantly more (8.7 % of the data) errors than related (6.0 %). Errors also differed significantly by Condition ($\chi^2(2)$ =22.35, $p < 0.0001$*): the Morphological Condition induced the fewest errors (8.6 % of the data); error rates for the Semantic and Form Conditions were similar at 13.3 % and 12.1 % respectively. There was no interaction between Prime Type and Condition with regards to errors ($\chi^2(2)$ =2.85, p = 0.24).

6.1.1.3. Comparison of direction: stem ~ prefixed priming. In Experiments 1a and 1b, results indicated effects of priming in the morphological condition and only in one priming configuration: stem words sped up responses to morphologically related prefixed targets (stem → prefixed). To confirm this, results from the morphologically related word pairs in Experiment 1a (stem → prefixed) and Experiment 1b (prefixed → stem) were analysed together (N = 1562). This model[14] contained an interaction between the fixed effects Configuration (stem → prefixed/prefixed → stem) and Prime Type (Related/Unrelated), and by-subject and by-item random intercepts. It also contained log-transformed[15] values for Reaction Time: profile log-likelihoods of reaction

[12] lmer(logReacTime~Related+(1|SJ) + (1|TARGET_LABEL), data = d)
[13] lmer(logReacTime~1 + (1|SJ) + (1|TARGET_LABEL), data = d)
[14] lmer(logReacTime~RELATED*DIRECTION+ (1| SJ) + (1 |Item)).
[15] RT was log-transformed in this analysis due to distinct skewing in the visual inspection of residuals. Although optimum λ = −0.95, the lower confidence limit exceeded −1.

Table 14
Mean reaction times in ms and error rates for prefixed ~ prefixed configurations (* denotes a significant effect).

Configuration:	Morph Pairs *dushkriti ~ shukriti* 'misdeed ~ good deed'			Sem Pairs *nir-bʰoe ~ dushahosh* 'fearless ~ audacity'			Form Pairs *prolipt̪o ~ onulipi* 'coated ~ imitation'		
	RT			RT			RT		
	R	UR	Effect	R	UR	Effect	R	UR	Effect
Prefixed ~ Prefixed	708	722	NS	692	717	NS	712	714	NS
	SE			SE			SE		
	6.8	6.9		7.4	8.6		10.5	11.3	

Table 15
Mean reaction times in ms and error rates for suffixed - suffixed configurations.

Configuration:	Morph Pairs *bʰaggoban ~ bʰaggohin* 'fortunate – fortuneless'			Sem Pairs *shokt̪iman ~ bɔloban* 'powerful – muscular'			Form Pairs *kolpona ~ kɔlongkito* 'imagination – tarnished'		
	RT			RT			RT		
	R	UR	Effect	R	UR	Effect	R	UR	Effect
Suffixed – Suffixed	714	717	NS	696	707	NS	705	725	NS
	SE			SE			SE		
	5.4	5.5		6.9	6.9		7.4	8.1	

Table 16
Effect sizes for all matched configurations as measured by Hedges' g with 95 % CI.

Configuration:	RT (SE)			
	R	UR	Effect	Effect size
Prefixed – Prefixed	708 (6.8)	722 (6.9)	NS	−0.09 [−0.22, 0.04]
Suffixed – Suffixed	714 (5.4)	717 (5.5)	NS	−0.02 [−0.12, 0.08]

times were generated via a Box-Cox transformation ($\lambda = -0.95$). This model appeared homoscedastic when inspected visually and significant differences were found when compared to a model[16] in which the interaction between fixed effects was removed ($\chi^2(1) = 17.18$, $p < 0.0001$*).

The model showed a significant interaction between Prime Type and Direction (Est. = 0.07, SE =0.02, $t = -4.15$) and this was further investigated in pairwise comparisons, where the above findings were confirmed: only the stem → prefixed configuration induced priming (Est. = 0.09, SE =0.01, $t = 7.57$). The effect size for the stem → prefixed configuration was $g = 0.42$ with 95 % CI [−0.27, 0.56]) (see Table 8). No priming was found for the prefixed → stem configuration (Est. = 0.02, SE = 0.01, $t = 1.42$) and the effect size for the prefixed → stem configurations, as measured by Hedges' g, was $g = 0.02$ with 95 % CI [−0.12, 0.16]), indicating no effect. (See Table 10.) (See Tables 12–18.)

6.1.2. Experiment 2a and 2b: stem ~ suffixed

Experiments 2a and 2b present results for the priming Configuration containing stems and suffixes: Experiment 2a utilised stem words as primes (e.g. [d̪ɑm → d̪ɑm-i], 'cost → costly') and Experiment 2b utilised suffixed words as primes ([d̪ɑm-i] → [d̪ɑm], 'costly → cost').

6.1.2.1. Experiment 2a: stem → suffixed priming. For the stem → suffixed configuration, outlier removal resulted in a loss of 1034 data points (17 % of data). After nonword removal, the optimal model to converge ($N = 2627$) contained an interaction between the fixed effects Condition and Prime Type, and by-subject and by-item random intercepts.[17] This model appeared homoscedastic when inspected visually and a significant difference was found when compared to a model in which the interaction was removed ($\chi^2(2) = 6.59$, $p = 0.037$*).[18] In a pairwise comparison, only morphological pairs showed priming (Est. = 26.98, SE =8.66, $t = 3.11$) (see Table 9). Semantically related words did not prime one another (Est. = −2.06, SE = 8.61, $t = -0.24$) nor did form-related words (Est. = 1.01,SE = 10.40, $t = 0.09$).

Error rates revealed that Prime Type (Related/Unrelated) had no effect ($\chi^2(1)$ =2.4, $p = 0.12$) on error rates: error rates were similar for both Unrelated and Related word pairs. Condition had a significant effect on error rates ($\chi^2(2)$ =11.17, $p = 0.004$*): form-related items induced significantly more errors (11.5 % of the data) than the Semantic and Morphological conditions (9.9 % and 8.3 % respectively). There was no interaction between Prime Type and Condition ($\chi^2(2)$ =4.96, $p = 0.08$).

6.1.2.2. Experiment 2b: suffixed → stem priming. For the suffixed → stem configuration, outlier removal resulted in a loss of 1173 data points (19 % of data. After nonword removal, the optimal model ($N = 2329$) to converge contained the fixed effect Prime Type, by-subject and by-item random intercepts, and by-subject random slopes for Prime Type.[19] This model also contained log-transformed values[20] for reaction time: profile log-likelihoods of reaction times were generated via a Box-Cox transformation ($\lambda = -0.78$). This model appeared homoscedastic when inspected visually. This model showed no significant difference to a model containing an interaction ($\chi^2(2)$ =2.63, $p = 0.27$), Removal of the fixed effect Condition showed no difference ($\chi^2(2)$ =2.20, $p = 0.33$) to the null model, but removing Prime Type[21] as a fixed effect generated a significant difference ($\chi^2(3)$ =49.7, $p < 0.0001$*). This indicated that Prime Type was the only significant effect on the data.

Error rates revealed that Prime Type (Related/Unrelated) had a

16 lmer(logReacTime~RELATED+DIRECTION+ (1 | SJ) + (1 |Item))

17 lmer(ReacTime~RELATED*CONDITION+ (1| SJ) + (1 |Target))

18 lmer(ReacTime~RELATED+CONDITION+ (1| SJ) + (1 |Target))

19 lmer(logReacTime~Related + (1| SJ) + (1 + Related|Target))

20 Although optimum $\lambda = -0.78$, RT was log-transformed in this analysis due to distinct skewing in the visual inspection of residuals. Crucially, a non-transformed analysis of the reaction time data in this experiment did not change the outcome.

21 lmer(logReacTime~ Condition + (1 | SJ) + (1 |Target))

Table 17
Mean reaction times in ms and error rates for prefixed → suffixed configurations.

Configuration:	**Morph Pairs** *nirlojjo→ lojjito* immodesty → embarrassed			**Sem Pairs** *d̪urjon → papi* villain → sinner			**Form Pairs** *prɑt̪ʰomik → t̪ʰɑmɑno* primary → stop		
	RT			**RT**			**RT**		
	R	**UR**	**Effect**	**R**	**UR**	**Effect**	**R**	**UR**	**Effect**
Prefixed → Suffixed	696	721	NS	739	717	NS	679	685	NS
	SE			**SE**			**SE**		
	7.2	8.0		7.2	9.2		8.1	9.1	

Table 18
Mean reaction times in ms and error rates for suffixed → prefixed configuration (∼ denotes a borderline effect).

Configuration	Morph Pairs *lojjito → nirlojjo* embarrassed → immodesty			Sem Pairs *papi → d̪urjon* sinner → villain			Form Pairs t̪ʰamɑno → prɑt̪ʰomik stop → primary		
	RT			**RT**			**RT**		
	R	**UR**	**Effect**	**R**	**UR**	**Effect**	**R**	**UR**	**Effect**
Suffixed → Prefixed	633	668	35∼	674	681	NS	632	649	NS
	SE			**SE**			**SE**		
	6.3	7.5		7.6	8.1		8.5	8.1	

significant effect ($\chi^2(1)$ =8.57, p = 0.003*) on error rates: unrelated word pairs resulted in significantly more errors than related. Errors also differed significantly by Condition ($\chi^2(2)$ =8.01, p = 0.018*): the Morphological Condition induced the fewest errors (8.6 % of the data). Errors for semantically related pairs led to a loss of 23 % of all responses, and form-related errors led to a loss of 38 % of responses. There was no interaction between Prime Type and Condition ($\chi^2(2)$ =0.49, p = 0.78).

6.1.2.3. Comparison of direction: stem ∼ suffixed priming. Results from the individual analyses of configurations only indicated effects of priming in the morphological condition, and only in one configuration (stem → suffixed): seeing a stem (e.g. [d̪ɑm], 'cost') facilitated significantly faster responses (35 ms) to morphologically related suffixed words (e.g. [d̪ɑmi] 'costly') than unrelated. To confirm this, results from the morphologically related word pairs in Experiment 1a (stem → suffixed) and Experiment 1b (suffixed → stem) were analysed together (N = 1858).

The model[22] contained an interaction between the fixed effects Direction (stem → suffixed/suffixed → stem) and Prime Type (Related/Unrelated), by-subject and by-item random intercepts. It also contained log-transformed[23] values for reaction time: profile log-likelihoods of reaction times were generated via a Box-Cox (Box & Cox, 1964) transformation (λ = −0.87). This model appeared homoscedastic when inspected visually and significant differences were found when compared to a model[24] in which the interaction between fixed effects was removed ($\chi^2(1)$ = 7.52, p = 0.006*).

The model showed a significant interaction between Prime Type and Direction (Est. = −0.04, SE =0.015, t = −2.744) and this was further investigated in pairwise comparisons, where the above findings were confirmed: only the stem → suffixed configuration induced priming (Est. = 0.06, SE =0.01, t = 5.40). The effect size for the stem → suffixed configuration was g = 0.27 with 95 % CI [−0.14, 0.40]) (see Table 11). No priming was found for the suffixed → stem configuration (Est. = 0.01, SE = 0.01, t = 1.38). The effect size for the suffixed → stem configurations, as measured by Hedges' g, was g = 0.04 with 95 % CI [−0.09, 0.17]), indicating no effect.

6.1.3. Comparison of affixed words with their stems (experiments 1 and 2 combined)

We found priming effects for configurations in which the prime was a stem and the target a morphologically related prefixed word ([ɑd̪or] – [ɔn-ɑd̪or], 'love → disrespect', 53 ms), and when the prime was a stem and tɑe target a morphologically related suffixed word ([d̪ɑm - d̪ɑm-i], 'cost → costly', 35 ms). When the prime was an affixed word, however, −be it prefixed or suffixed- no facilitation for morphologically related words was found.

To investigate this further, we ran an analysis on the morphological word pairs in Experiments 1 and 2 to examine degree of priming across the experiments. The optimal model to converge[25] contained an interaction between Prime Type (Related/Unrelated) and Target Type (Stem/Affixed), and random slopes and intercepts for subjects and items. It also contained log-transformed values for reaction time: profile log-likelihoods of reaction times were generated via a Box-Cox transformation (λ = −0.91). There was a significant interaction between Prime Type and Target Type (Est. = 5.347e-02, SE = 1.15e-02, t = 4.67) which supported our finding of the stem prime advantage: when the target was a stem, neither suffixed nor prefixed words provided a facilitation in responses. When the target was an affixed word, however, there was priming for both configurations: prefixed and suffixed primes. This is reflected in the effect sizes: for the stem → affixed configurations, the effect size, as measured by Hedges' g, was g = 0.34 with 95 % CI [0.24, 0.43]); for the affixed → stem configurations, it was g = 0.03 with 95 % CI [−0.07, 0.12]). Error rates revealed that, in the morphological condition, errors were significantly ($\chi^2(1)$ =7.8, p = 0.005*) lower overall for stem targets (3.6 %) than for affixed targets (5.6 %).

Effect sizes for the stem → affixed configurations also pointed toward an asymmetry in the degree of priming between stem → prefixed words and stem → suffixed words. When the target was a stem, there was no difference in the degree of priming (there was none). When the target was affixed, however, stem → prefixed words generated a medium effect of g = 0.42 with 95 % CI [0.27, 0.56]). Suffixed words generated a small effect of g = 0.27 with 95 % CI [0.14, 0.40]). Thus, it seems that Bengali stem words may have primed related prefixed words more (53 ms) than they primed suffixed words (35 ms).

[22] lmer(logReacTime∼related*direction+ (1| SJ) + (1 |Item)).
[23] RT was log-transformed in this analysis due to distinct skewing in the visual inspection of residuals. Although optimum λ = −0.87, the lower confidence limit exceeded −1.
[24] lmer(logReacTime∼related+direction+ (1 | SJ) + (1 |Item))
[25] logReacTime∼Related*Target_Is+(1 |Subject) + (1 |Target)

6.1.4. Discussion

From the results presented above, a clear asymmetry emerges where stem primes provided an advantage that was not replicated by affixed primes. Asymmetries in priming appeared when we examined the differences between the configurations tested in Experiments 1 and 2. Seeing a stem word as a prime and a morphologically related affixed words as a target elicited similar priming effects: results showed that stems boosted recognition of both prefixed and suffixed words that were related morphologically to the stem. When the prime was an affixed word, prefixed words did not elicit a reliable priming effect for morphologically related stems. The effect was also very small for the suffixed → stem configurations. The differences between directional configurations (e.g. stem → prefixed/prefixed → stem) suggested a much stronger effect between prefixed word pairs than suffixed word pairs. If nothing else, stem → prefixed words (53 ms) elicited the strongest effect of priming across all configurations.

In visual delayed conditions, the stem advantage emerges: the strong priming results for both stem → prefixed words and stem → suffixed words lend support to the idea that seeing a stem facilitates visual recognition of a related affixed target. This recognition becomes harder when the visual prime is an affixed word, and it becomes especially hard when the prime is a prefixed word. Once again, we have evidence that the relationship between a suffixed form and its stem is not entirely equivalent to that between a prefixed form and its stem. To further investigate this asymmetry, we turn to comparisons which remove the stem advantage.

6.2. Priming configurations containing affixed words

6.2.1. Matched pairs

6.2.1.1. Experiment 3: prefixed-prefixed priming. This experiment tested for semantic, morphological and form priming for Bengali prefixed words (e.g. [d̪uʃ-krit̪i ~ ʃu-krit̪i], 'misdeed – good deed'): thus, prefixed words served both as prime and target in this experiment. Responses were coded for Condition (Semantic/Morphological/Form) and Prime Type (Related/Unrelated). Outlier removal resulted in a loss of 2067 data points (24 % of the data). After nonword removal, the optimal model ($N = 1962$) to converge was the null model.[26] This model showed no significant difference to a model in which Condition was added[27] ($\chi^2(2) = 0.18$, $p = 0.91$), nor one in which Prime Type was added ($\chi^2(1) = 2.36$, $p = 0.12$). To summarise, prefixed primes did not facilitate responses to related prefixed targets, whether they were related semantically, orthographically, or morphologically.

Errors for this Configuration were high, most notably in the form condition where 53 % of the data was lost due to errors. This rate differed significantly ($\chi^2(2) = 25.5$, $p \leq 0.0001^*$) from the data lost due to errors from the semantic condition (22 %) and the morphological condition (26 %). Unrelated primes also generated significantly higher number of errors than related $\chi^2(2) = 19.7$, $p \leq 0.0001^*$), but there was no indication that this varied significantly by Condition ($\chi^2(2) = 3.87$, $p = 0.14$). There was no interaction.

6.2.1.2. Experiment 4: suffixed-suffixed priming. This experiment tested for semantic, morphological and form priming for Bengali suffixed words (e.g. [bʰɑgːo-ban ~ bʰɑgːo-hin], 'fortunate ~ fortuneless'). Responses were coded for Condition (Semantic/Morphological/Form) and Prime Type (Related/Unrelated). Outlier removal resulted in a loss of 1880 data points (21.6 % of the data). After nonword removal ($N = 3317$), the optimal model[28] contained the fixed effect Prime Type, random slopes in the by-subject and by-item analyses, and random intercepts for Prime Type in the by-item analyses. This model showed no significant difference to a model[29] that included Condition as a fixed effect ($\chi^2(2) = 2.13$, $p = 0.34$). The effect of Prime Type (Est = 19.0, SE = 6.3, $t = 2.93$) was significant: related items overall generated faster reaction times than unrelated items, but this did not vary by Condition.

Errors differed significantly ($\chi^2(2) = 12.38$, p = 0.002*) across the conditions: more data was lost (20.9 %) from the semantic pairs than the other two conditions (17.4 % average for the two). There was no difference in the number of errors for Related (18.29 %) versus Unrelated Primes ($\chi^2(1) = 0.06$, $p = 0.73$) nor was there an interaction ($\chi^2(2) = 0.63$, $p = 0.72$).

6.2.1.3. Comparison of prefixed-prefixed to suffixed-suffixed. Results from the individual analyses of configurations resulted in no priming effects for any configuration: prefixed primes did not prime related prefixed targets (e.g. [d̪uʃ-krit̪i ~ ʃu-krit̪i], 'misdeed – good deed'): for any of the three types of word pairs, nor did suffixed primes facilitate responses to any related suffixed targets (e.g. [bʰɑgːo-ban ~ bʰɑgːo-hin], 'fortunate – fortuneless'). Morphologically related prefixed words elicited faster overall responses than suffixed words (Est. = 17.7, SE = 4.98, $t = 3.56$),[30] but there was no effect of Relatedness within this condition. In the morphological condition, an examination of effect sizes showed a similar result: the effect size for the prefixed – prefixed configurations, as measured by Hedges' g, was $g = -0.09$ with 95 % CI [−0.22, 0.04]) and the effect size for the suffixed – suffixed configuration was $g = -0.02$ with 95 % CI [−0.12, 0.08]) (see Table 19).

6.2.1.4. Discussion. In Experiments 3 (prefixed – prefixed) and 4 (suffixed – suffixed), we found no effects of priming for any configuration. In our critical condition, prefixed words did not prime other morphologically related prefixed words (e.g. [d̪uʃ-kriti] ~ [ʃu-krit̪i], 'misdeed – good deed'), nor did suffixed words prime other suffixed words that shared the same stem (e.g. [bʰɑgːo-ban ~ bʰɑgːo-hin], 'fortunate – fortuneless'). Here, the effect of error loss is clear: significantly more data was lost for all three conditions (morphological, semantic and form) in the prefixed – prefixed configuration than for the suffixed – suffixed configuration. This resulted in imbalanced sample sizes, particularly for the morphological condition where N = 1962 in the prefixed – prefixed configuration and N = 3317 in the suffixed – suffixed configuration. While it was clear there was no evidence of priming in either experiment, the high error rates for the prefixed – prefixed word pairs point to an additional processing difficulty. To examine this further, we looked at how mismatched (i.e. *prefixed ~ suffixed*) affixed word pairs sharing the same stem were processed in visual delayed priming conditions.

6.2.2. Mismatched pairs

Experiments 5a and 5b present results for the priming configuration containing stems and prefixes: Experiment 5a utilised prefixed words as primes and suffixed words as targets (e.g., [nir-loʤːo] → [loʤː-ito], 'immodesty – embarrassment') and Experiment 5b tested the opposite direction with suffixed words as primes and prefixed words as targets ([loʤː-ito] → [nir-loʤːo] 'embarrassed → immodesty').

6.2.2.1. Experiment 5a: prefixed→ suffixed priming. This experiment tested for semantic, morphological and form priming for Bengali prefixed primes and suffixed targets (e.g. [nir-loʤːo] → [loʤː-ito], 'immodesty – embarrassment'). Responses were coded for Condition (Semantic/Morphological/Form) and Prime Type (Related/Unrelated). Outlier removal resulted in a loss of 1338 data points (21 % of the data).

[26] lmer(ReacTime~1+ (1|SJ) + (1|Target), data = d)
[27] lmer(ReacTime~RELATED+ (1|SJ) + (1|Target), data = d)
[28] lmer(logReacTime~RELATED + (1| SJ) + (1 + RELATED|Target), data = d)
[29] lmer(logReacTime~RELATED+CONDITION+ (1| SJ) + (1 + RELATED| Target), data = d)
[30] ReacTime~RELATED*Target_Type + (1| SJ) + (1 |Item)

After nonword removal, the optimal model ($N = 2244$) to converge was the null model.[31] A model containing the fixed effect Related[32] showed no difference to the null model ($\chi^2(2) = 3.7$, $p = 0.05$), nor did a model containing Condition[33] ($\chi^2(2) = 4.6$, $p = 0.09$). The null model appeared homoscedastic when inspected visually.

Errors differed significantly ($\chi^2(2) = 21.3$, p ≤ 0.0001*) depending on whether the prime was related or unrelated to the target: control words elicited a significantly higher number of errors (10.3 % of data) than related words (4.7 %). There was no difference in error rates across conditions ($\chi^2(2) = 0.156$, $p = 0.92$) nor was there an interaction.

6.2.2.2. Experiment 5b: suffixed → prefixed priming. This experiment tested for semantic, morphological and form priming for Bengali suffixed primes and prefixed targets (e.g. [lodʒ:-ito] → [nir-lɔdʒ:o], 'embarrassed → immodesty'). Responses were coded for Condition (Semantic/Morphological/Form) and Prime Type (Related/Unrelated). Outlier removal resulted in a loss of 1044 data points (26 % of the data). After nonword removal, the optimal model ($N = 2533$) to converge contained the fixed effect Prime Type, and by-subject and by-item intercepts. No differences were found for a model containing Condition[34] in an interaction ($\chi^2(2) = 1.88$, $p = 0.39$) and inclusion of Condition as a fixed effect elicited a marginal, borderline effect ($\chi^2(2) = 2.53$, $p = 0.063$). Removing Prime Type from the model elicited a significant difference in model fit ($\chi^2(1) = 9.52$, p $= 0.002$*), suggesting that related words were overall faster than unrelated words across conditions. This model appeared homoscedastic when inspected visually. The model reported a significant effect of Prime Type (Est. $= -0.03$, SE $= 0.009$, $t = -3.06$). Post-hoc analyses revealed priming in the morphological condition (Est. $= 24.3$, SE $= 9.36$, $t = 2.59$), but effect sizes for this condition were small, as measured by Hedges' *g*, $g = 0.25$ with 95 % CI [0.12, 0.39].

Error rates showed that errors differed depending on both Condition and Prime Type ($\chi^2(2) = 21.33$, $p < 0.001$*). There was a significant difference in errors: more data was lost for related than unrelated prime types in the morphologically and semantically related conditions. Error types were constant for form related pairs.

6.2.2.3. Comparison of direction: prefixed ~ suffixed. Results from the individual analyses of configurations only indicated effects of priming in the morphological condition, and only one configuration approached significance (suffixed → prefixed): seeing a suffixed word facilitated what appeared to be mariginally faster responses (35 ms) to morphologically related prefixed words (e.g. [lodʒ:-ito] → [nir-lɔdʒ:o], 'immodest → embarrassed') that shared the same stem ([lɔdʒ:ɑ], 'shame'). This was not the case when the prime was a prefixed word and the target a suffixed word ([nir-lɔdʒ:o] → [lodʒ:-ito] 'immodesty → embarrassed'). To examine this more fully, results from the morphologically related word pairs in Experiment 5a and 5b were analysed together.

Responses were coded for Condition (Semantic/Morphological/Form), Direction (Prefixed → Suffixed /Suffixed → Prefixed) and Prime Type (Related/Unrelated). The optimal model ($N = 4777$)[35] to converge contained the fixed effects Prime Type and Direction, and by-subject and by-item intercepts. A model containing the fixed effect Condition[36] showed no difference to our model ($\chi^2(2) = 3.67$, $p = 0.15$). This model appeared homoscedastic when inspected visually and significant differences were found when compared to a model where either fixed effect was removed. This model showed a significant effect of Prime Type, where related words generated faster responses overall than unrelated words, and Direction, where responses in the Prefixed → Suffixed configuration were overall slower than those for Suffixed → Prefixed.

Crucially, however, this did not differ across Conditions (as evidenced by model comparison as reported above), nor was there an interaction between Related/Unrelated words and direction of presentation (Prefixed → Suffixed /Suffixed → Prefixed), indicating no priming effect for either configuration (also evidenced by model comparison as reported above). Recall that the inclusion of Condition as a fixed effect in the Suffixed → Prefixed configuration was marginal ($\chi^2(2) = 2.53$, p $= 0.063$); this as well as a comparison of effect sizes (both small, see Table 19 below) lends credibility to the finding that there was no reliable effect of priming in this experiment.

Table 19
Reaction times and effect sizes for all mismatched configurations (Hedges *g* with 95 % CI).

Configuration:	Morph Pairs *nirlojjo ~ lojjito* immodesty ~ embarrassed		
	RT		
	R	UR	Effect Size
Prefixed → Suffixed	663	683	0.16 [0.02, 0.30]
Suffixed → Prefixed	633	670	0.25 [0.12, 0.39]

7. General discussion

Across a wide range of priming studies (masked, cross-modal, visual), morphologically related words have been shown to regularly speed response times to one another (cf. Crepaldi et al., 2016). However, there are also robust experimental findings that suggest prefixed words and suffixed words may be processed differently: while configurations for morphologically associated pairs containing prefixed words (e.g. *pure ~ impure*) have generally elicited strong evidence of priming, configurations containing suffixed words have consistently revealed less evidence of facilitation- particularly when the affixed word is presented visually (Comstock, 2018; Feldman & Soltano, 1999; Gonnerman & Andersen, 2000; Reid et al., 2003; Feldman et al., 2004; cf. Crepaldi et al., 2016; Wynne et al., 2021). These findings raise questions about the effects that phonological asymmetries can have upon orthographic complexity in the processing of words, particularly across different priming paradigms.

As we saw in Section 1, there are phonological processes in Bengali that can affect how graphemes are written in the language. For example, in the suffixed word [ʃɑririk] 'bodily' (Example 16 below), the stem has undergone two phonological changes: 1) vowel lowering of [o] to [ɑ] in the stem and 2) resyllabification after suffixation of [ik]: [ʃ**or**.rir] ~ [ʃ**ɑ**.ri.rik]. This has triggered a complementary orthographic change, where the affix's vowel is realised as a vocalic diacritic written inside the boundaries of the stem:

Example 16: [ʃorir-ik] > [ʃɑririk] 'bodily'

underlying form	1) vowel lowering	2) resyllabification
/ʃorir-ik/	/ʃɑrir-ik/	[ʃɑ.ri.rik]
শরীর-ইক	শারীর-ইক	শারীরিক

The asymmetry in the frequency and types of alternations that occur at the edge of affixed words entails that phonological features of suffixes are more likely to affect the stem (as in Example 16 above), while phonological features of prefixes are more likely to be affected **by** material in the stem.

[31] lmer(ReacTime~1 + (1|SJ) + (1|TARGET_LABEL)
[32] lmer(ReacTime~Related + (1|SJ) + (1|TARGET_LABEL)
[33] lmer(ReacTime~Condition + (1|SJ) + (1|TARGET_LABEL)
[34] lmer(ReacTime~Related + (1|SJ) + (1|TARGET_LABEL)
[35] lmer(ReacTime~RELATED+ DIRECTION+ (1| SJ) + (1|TARGET_LABEL), data = d)
[36] lmer(ReacTime~RELATED+CONDITION+DIRECTION+ (1| SJ) + (1| TARGET_LABEL), data = d)

In our study, we tested priming for morphologically related Bengali words in a visual delayed priming paradigm: by manipulating the positioning of an affix relative to a shared stem, we examined relationships not only between isolated stems and related affixed words (e.g. [bʰɑgːo] ∼ [bʰɑgːo-hin], 'luck ∼ luckless'), but also affixed words related by the same stem (e.g. [d̪ur- bʰɑgːo ∼ bʰɑgːo-hin], 'misfortune ∼ luckless'). We chose to present these words as pairs separated by a lag (5–7 intervening items) in order to truly isolate effects of morphological overlap from those for semantic or phonological relationships. Following on results from cross-modal experiments (Wynne et al., 2021), (e.g. [d̪ur-bʰɑgːo] ∼ [bʰɑgːo-hin], 'misfortune ∼ luckless'), we expected that affixed words would be harder to decompose in the visual delayed modality where no auditory information is provided. We also predicted an asymmetry in the ease of decomposition due to asymmetrical phonological (and therefore orthographic) alternations that occur during affixation. Our questions pivoted not only on the effect of phonological processes (and subsequent orthographic complexities), but also on the effect that the modality of prime presentation (e.g. visual or auditory) has upon our understanding of morphological decomposition of complex words.

7.1. Findings for stem ∼ affixed configurations

In Experiments 1 (stem ∼ prefixed) and 2 (stem ∼ suffixed), we tested for priming in morphologically, semantically, and form related word pairs. In these experiments, stems served as either primes or targets for affixed words. Across these experiments, no effect of semantic (e.g. [ʃɑhoʃ] ∼ [nir-bʰɔe], 'courage ∼ unafraid') or form relation (e.g. [bɑʃɑ ∼ ɔboʃɔr], 'home ∼ leisure') was found. For morphologically-related items, we found a clear effect of stem priming: seeing a related stem word as a prime facilitated responses to both prefixed and suffixed words (i.e. stem → affixed). In a comparison of priming effects between the two different types of affixed words in the stem → affixed configurations, we found an asymmetry in the degree of priming. Bengali stem words primed related prefixed words more (53 ms) than they primed suffixed words (35 ms). When the target was a stem, however, neither suffixed nor prefixed primes provided a facilitation in responses.

Within the psycholinguistic literature, it has been suggested that there is a processing advantage for stem-initial words, since the stem's semantic and phonological information is perceived first in these items (Cutler et al., 1985, Hawkins & Gilligan, 1988; Plag & Baayen, 2009). However, this diverges from findings throughout the behavioural literature: configurations containing suffixed words tend to generate less reliable priming evidence, particularly when the target is presented visually. While no reliable data exists (to our knowledge) for stem → prefixed priming in a visual delayed presentation, our results seem to agree with existing findings for stem → suffixed priming (Feldman & Larabee, 2001; Gaston et al., 2021): as long as an isolated stem is given first, morphologically related suffixed targets will result in speeded response times.

When the stem is no longer serving as the prime (i.e. affixed → stem configurations), the story changes considerably: neither prefixed words nor suffixed words reliably primed morphologically related stems in our experiments. This is surprising, as affixed → stem configurations have elicited some of the most homogenous results for priming across paradigms and modalities (cf. Grainger et al., 1991; Taft, 2003; Rastle et al., 2004; Taft & Kougious, 2004; Longtin & Meunier, 2005; also Rastle & Davis, 2003; Rastle et al., 2000; and Longtin et al., 2003). However, it seems there is some evidence of atypicality in visual delayed experiments: while Feldman & Larabee (2001) found reduced priming for suffixed → stem word pairs in Hebrew, Gaston et al. (2021) reported no priming for these pairs in English.

Clearly, the advantage provided by seeing a stem as a prime is significant for accessing the internal structure of a visually presented, morphologically complex word in Bengali. Crucially, however, the boost is not equal for prefixed words and suffixed words: our results suggested that, when provided with a stem first, prefixed words were easier to decompose than suffixed words. Recall that, in suffixed words such as [ʃikʰː-ito], 'educated' (Example 18 below; from stem [ʃikʰːɑ] 'knowledge'), phonological processes are more likely to affect the shape of the stem of a suffixed word than a prefixed word. In the case of [ʃikʰː-ito], the final vowel of the stem [ʃikʰːɑ] has deleted before the vowel initial suffix, and the [kʰ] has become the onset of the vowel of the suffix, /ʃik.kʰɑ–i.t̪o/ > [ʃikʰːi.t̪o].

Example 17. **[**ʃikkʰito] 'educated'.

Stem	Suffix	**Suffixed**
শিক্ষা	-ইত	শিক্ষিত

In prefixed words, although the prefix shape changes, the stem generally remains intact during affixation. In the prefixed word *on-ador*, 'disrespect' (Example 17), resyllabification causes the [n] of the prefix to become the onset of the first syllable of the stem: [ɑ.d̪or] ∼ [ɔ.**nɑ**.d̪or], resulting in the the syllable [nɑ] which is written as a nasal plus [ɑ] as the diacritic: না.

Example 18. *on-ador*, 'disrespect'.

underlying form	**prefixed form**
/ɔn.-ɑ.dor/	[ɔ.nɑ.dor]
অন-আদর	অনাদর

Our findings for the stem → affixed configurations are in line with the prefixing advantage observed in the empirical and experimental literature: stems primed prefixed words more than they primed suffixed words in this experiment, similar to the findings in the cross-modal environment (Wynne et al., 2021). This suggests that having clearly defined morpheme boundaries in the prime allows for easier decomposition of the target word when you only have visual information to work with; however, even with these clear boundaries, the differences between prefixed words and suffixed words become evident in the priming results. Notably, any advantage disappears in the visual delayed priming environment when primes are Bengali affixed words: neither prefixed words nor suffixed words (e.g. [d̪ur-bʰɑgːo], 'bad luck'; [bʰɑgːo -bɑn], 'lucky') were able to facilitate access to morphologically related words ([bʰɑgːo], 'luck'). In order to investigate this further, we next ran a series of experiments containing only affixed words.

7.2. Affixed ∼ affixed configurations

Indeed, the lack of priming for affixed primes continued with our second group of experiments. In Experiments 3, 4 and 5, we systematically varied the relationships between affixed words: Experiment 3 compared priming for morphologically related Bengali prefixed words, Experiment 4 compared Bengali suffixed words, and Experiment 5a and 5b examined both directions of prefixed ∼ suffixed configurations. Across these experiments, the only configuration that came close to priming was the suffixed → prefixed configuration, and the effect was not particularly strong. These results were noticeably different to those in our cross-modal study (2021), which found strong priming across all relationships (and a stronger effect for prefixed-prefixed pairs than suffixed-suffixed pairs) as well as visual delayed experiments in English (cf. Feldman & Larabee, 2001), who reported priming for suffixed ∼ suffixed pairs (*payment* ∼ *payable*) and weak priming for prefixed → suffixed pairs (e.g. *prepay* → *payment*).

Perhaps the most surprising result was that of our prefixed-prefixed word pairs; not only did morphologically related prefixed – prefixed word pairs fail to prime, they also elicited the highest rate of errors across all five experiments. Our predictions for these experiments centred on difficulty that readers might have when decomposing visually presented affixed words without any auditory input: we expected that the orthography alone would not induce complexity for a native reader, but rather the changes that occur across stem – affix boundaries might make the process of accessing the stem more difficult. Indeed, this appears to be the case: prefixed words, which appear privileged for stem access when primed with the same stem, no longer prime- likewise, suffixed words no longer prime either.

7.3. Summary and future directions

To summarise, we only found priming in the visual delayed environment when a stem word preceded a morphologically related affixed word, and the degree of priming depended on the position of the stem in the target. All configurations containing affixed words as primes failed to elicit priming in visual delayed conditions. Thus, it appears that orthographic complexity can play a role in stem access in morphologically complex words. In speech, Bengali affixed words (and in particularly prefixed words) are often easily distinguishable despite undergoing phonological processes such as assimilation -thus the stem can easily be more easily located. This is not always the case with the written forms of words in the language, as we have seen from the varying amounts of orthographic complexity caused by phonological alternations during affixation, particularly for suffixed words. The experiments reported above provide original evidence for the interaction between orthography, phonology, and morphology in the processing of morphologically complex words. Bengali affixing morphology has permitted us to investigate the effects of orthographic complexity caused by phonological processes in all directions of affixation. We maintain that derivationally complex words are always decomposed in processing. However, in a visual priming (delayed) study, we have found evidence that, in a language which has significant orthographic depth, seeing the stem allows affixed words to be easily activated. In this case, the priming results show that the affixed words themselves must be decomposed and the stem extracted, otherwise no priming would have been observed (e.g., [d̪in]$_{\text{STEM}}$ > [ʃu-d̪in]$_{\text{SUFFIX}}$ [d̪oin-ik]$_{\text{PREFIX}}$). When the affixed word is the prime, it too must be decomposed; but the affixed word would have undergone phonological rules or resyllabification at either affix boundary (/d̪ur-aʃa/ > [d̪u.rɑʃɑ] vs. [d̪oi.nik] < /d̪in-ik/). In order to extract the stem, one must undo the orthographic intricacies caused by the morphophonological alternations (such as resyllabification and diphthongisation), thus slowing down the process. By the time a related affixed word or stem target is visible, after 5 to 7 intervening (unrelated) words, the priming effect is diminished enough to result in no priming for any of the configurations in which an affixed word was shown as a prime.

From the evidence presented here, we do not know which type of morphophonological rule (assimilation, dissimilation, deletion, epenthesis or resyllabification) reduces or thwarts access of the stem (if at all). Our stimuli contained a wide variety of morphophonological alternations (as is representative of the language itself) which disallowed any reliable subset analyses to be run. Of course, as we have seen from Tables A and B in Section 2, these effects are not translated into equal orthographic intricacy at the prefix and suffix edges: the effects of morphophonological rules on the orthography vary considerably (e.g. stem vowel alternation, coda consonant assimilation, resyllabification). Resyllabification at the prefix end somewhat conceals the initial vowel of the stem (/d̪ur-aʃa/ > [d̪u.rɑʃɑ]), while resyllabification at the suffix edge, moves the coda consonant of the stem but the onset of the stem remains untouched (/gæn-i/ > [gæ.ni]). Bengali continues to be an ideal language to study because unlike many other languages, the morphophonological consequences are observable at both affix edges. To disentangle the morphophonological effects from the orthographic intricacies, we suggest further studies in which each element is controlled separately.

Credit authorship contribution statement

Hilary S.Z. Wynne: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Beinan Zhou:** Methodology, Investigation, Data curation, Conceptualization. **Sandra Kotzor:** Writing – original draft, Methodology, Investigation, Conceptualization. **Aditi Lahiri:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation.

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Appendix A. Test conditions

Table A.1
Morphologically Related pairs.

	Ex 1: Stem ↔ Prefix	Ex 2: Stem ↔ Suffix	Ex 3: Prefix → Prefix	Ex 4: Suffix → Suffix	Ex 5: Prefix ↔ Suffix
Prime	আদর [ɑd̪or] 'fondness'	রুপো [rupo] 'silver'	দুষ্কৃতী [d̪uʃkrit̪i] misdeed	ভাগ্যবান [bʰɑgːoban] 'fortunate'	নির্লজ্জ [nirlɔdʒːo] 'immodesty'
Target	অনাদর [ɔnɑd̪or] 'disrespect'	রুপালি [rupoli] 'silvery'	সুকৃতি [ʃukrit̪i] 'good deed'	ভাগ্যহীন [bʰɑgːohin] 'unfortunate'	লজ্জিত [lodʒːit̪o] 'embarrassed'

Table A.2
Form Related pairs.

	Ex 1: Stem ~ Prefix	Ex 2: Stem ~ Suffix	Ex 3: Prefix – Prefix	Ex 4: Suffix – Suffix	Ex 5: Prefix ~ Suffix
Prime	বাসা [bɑsha] 'home'	লেখা [lek^{h}ɑ] 'entry'	প্রলিপ্ত [prolipt̪o] 'coated'	কল্পনা [kɔlponɑ] 'imagination'	প্রাথমিক [pr*a*t̪^{h}omik] 'primary'
Target	অবসর [ɔboshɔr] 'leisure'	লেপন [lepɔn] 'coating'	অনুলিপি [onulipi] 'imitation'	কলংকিত [kɔloŋkit̪o] 'tarnished'	থামানো [t̪^{h}ɑmɑno] 'stop'

Table A.3
Semantically Related pairs.

	Ex 1: Stem ~ Prefix	Ex 2: Stem ~ Suffix	Ex 3: Prefix – Prefix	Ex 4: Suffix – Suffix	Ex 5: Prefix ~ Suffix
Prime	সাহস [ʃɑhoʃ] 'courage'	নিদ্রা [nid̪rɑ] 'sleep'	নির্ভয় [nirb^{h}ɔe] 'without fear'	শক্তিমান [ʃokt̪imɑn] 'powerful'	দুর্জন [d̪urdʒon] 'villain'
Target	নির্ভয়ে [nirb^{h}ɔe] 'without fear'	ঘুমন্ত [g^{h}umont̪o] 'sleepy'	দুঃসাহস [d̪uʃːɑhoʃ] 'audacity'	বলবান [bɔlobɑn] 'muscular'	পাপী [pɑpi] 'sinner'

Appendix B. Test stimuli

1. Experiment 1: test items for the stem ↔ prefixed (morphologically related) configuration

	Stem Items			Prefixed Items		
1	ɑd̪or	আদর	*respect*	ɔn-ɑd̪or	অনাদর	*disrespect*
2	gɔnd̪ho	গন্ধ	*odour*	dur-gɔnd̪ho	দুর্গন্ধ	*malodour*
3	ʧenɑ	চেনা	*familiar*	ɔ-ʧenɑ	অচেনা	*unfamiliar*
4	g^{h}ɔʈonɑ	ঘটনা	*event*	dur-g^{h}ɔʈonɑ	দুর্ঘটনা	*misadventure*
5	k^{h}ɔbor	খবর	*news*	ʃu-k^{h}ɔbor	সুখবর	*good news*
6	ʃɑb^{h}ɑbik	স্বাভাবিক	*natural*	ɔ-ʃːɑb^{h}ɑbik	অস্বাভাবিক	*unnatural*
7	ʤɔe	জয়	*opportunity*	pɔrɑ-ʤɔe	পরাজয়	*defeat*
8	ʃɔbd̪o	শব্দ	*talk*	ni-ʃːɔbd̪o	নিঃশব্দ	*silence*
9	ɑʃɑ	আশা	*hope*	nir-ɑʃɑ	নিরাশা	*greed*
10	ʧoritro	চরিত্র	*character*	ku-ʧoritro	কুচরিত্র	*bad character*
11	purno	পূর্ণ	*complete*	ɔ-purno	অপূর্ণ	*incomplete*
12	ɑ̃t̪ːɑ	আত্মা	*ego*	dur-ɑ̃t̪ːɑ	দুরাত্মা	*villain*
13	ʤibon	জীবন	*life*	ɑ-ʤibon	আজীবন	*until death*
14	prɑpːo	প্রাপ্য	*available*	d̪uʃ-prɑpːo	দুষ্প্রাপ্য	*rare*
15	d̪ɔrʃon	দর্শন	*view*	ʃu-d̪ɔrʃon	সুদর্শন	*presentable view*
16	biʧɑr	বিচার	*judgement*	ʃu-biʧɑr	সুবিচার	*correct judgement*

2. Experiment 2: test items for the stem ↔ suffixed (morphologically related) configuration.

	Stem Items			Suffixed Items		
1	d̪am	দাম	*cost*	d̪am-i	দামি	*costly*
2	d̪ukʰ:o	দুঃখ	*sorrow*	d̪ukʰ:-it̪o	দুঃখিত	*sorrowful*
3	lobʰ	লোভ	*greed*	lobʰ-onio	লোভনীয়	*covetable*
4	ʃorir	শরীর	*body*	ʃarir-ik	শারীরিক	*corporal*
5	lɔʤ:ɑ	লজ্জা	*shame*	laʤ-uk	লাজুক	*bashful*
6	manuʃ	মানুষ	*mortal*	manoʃ-ik	মানসিক	*merciful*
7	d̪in	দিন	*day*	d̪oin-ik	দৈনিক	*daily*
8	iʧʰ:ɑ	ইচ্ছা	*wish*	iʧʰ:-uk	ইচ্ছুক	*wishful*
9	peʈ	পাঠ	*stomach*	peʈ-uk	পেটুক	*glutton*
10	ʤoɽ	জোর	*force*	ʤoɽ-ɑlo	জোরালো	*forceful*
11	ʤat̪i	জাতি	*nation*	ʤat̪-io	জাতীয়	*national*
12	bʰut	ভূত	*ghost*	bʰout-ik	ভূতইক	*ghostly*
13	naʈok	নাটক	*drama*	naʈok-io	নাটকীয়	*dramatic*
14	kokʰ	চক্ষু	*the eye*	kakk-uʃ	চাক্ষুষ	*visual*
15	ɔporad̪ʰ	অপরাধ	*crime*	ɔporad̪ʰ-i	অপরাধী	*criminal*
16	ʃonɑ	সোনা	*gold*	ʃonɑ-li	সোনালী	*golden*

3. Experiment 3: test items for the prefixed ↔ prefixed (morphologically related) configuration

	Prefixed Items			Prefixed Items		
1	d̪ur-d̪in	দুর্দিন	*bad days*	ʃu-d̪in	সুদিন	*happy days*
2	ku-bud̪ʰ:i	কুবুদ্ধি	*lack of judgment*	d̪ur-bud̪ʰ:i	দুর্বুদ্ধি	*mischief*
3	d̪ur-bʰɑbnɑ	দুর্ভাবনা	*misery*	nir-bʰɑbnɑ	নির্ভাবনা	*intrigue*
4	ɔ-ʧɑlok	অচালক	*passenger*	pori-ʧɑlok	পরিচালক	*director*
5	ku-ʧorit̪ro	কুচরিত্র	*bad character*	d̪uʃ-ʧorit̪ro	দুশ্চরিত্র	*wicked*
6	ku-ʧint̪ɑ	কুচিন্তা	*evil thought*	d̪uʃ-ʧint̪ɑ	দুশ্চিন্তা	*anxiety*
7	d̪uʃ-krit̪i	দুষ্কৃতী	*miscreant*	ʃu-krit̪i	সুকৃতি	*virtue*
8	d̪ur-bɑk:o	দুর্বাক্য	*abusive language*	prot̪i-bɑk:o	প্রতিবাক্য	*the opposite*
9	ku-puruʃ	কুপুরুষ	*bad person*	ʃu-puruʃ	সুপুরুষ	*nice person*
10	prot̪i-rud̪ʰ:o	প্রতিরুদ্ধ	*besieged*	ni-rud̪ʰ:o	নিরুদ্ধ	*obstructed*
11	ku-lokʰ:on	কুলক্ষণ	*bad omen*	ʃu-lokʰ:on	সুলক্ষণ	*good omen*
12	ʃu-ʃɔŋbɑd̪	সুসংবাদ	*good news*	d̪uʃ-ʃɔŋbɑd̪	দুঃসংবাদ	*bad news*
13	dur-mul:o	দুর্মূল্য	*high priced*	ɔ-mul:o	অমূল্য	*priceless*
14	ʃu-nit̪i	সুনীতি	*morals*	d̪ur-nit̪i	দুর্নীতি	*corruption*
15	ɔ-ʃɔmɔe	অসময়	*inappropriate time*	d̪uʃ-ʃɔmɔe	দুঃসময়	*bad times*
16	ʃu-ʃɔpno	সুস্বপ্ন	*good dreams*	d̪uʃ-ʃɔpno	দুঃস্বপ্ন	*nightmare*
17	ɔ-ʃɑd̪ʰ:o	অসাধ্য	*unbearable*	d̪uʃ-ʃɑd̪ʰ:o	দুঃসাধ্য	*arduous*
18	niʃ-prɑp:o	নিষ্পাপ	*noteworthy*	d̪uʃ-prɑp:o	দুঃস্প্রাপ্য	*rare*
19	ʃu-gɔnd̪ʰo	সুগন্ধি	*fragrance*	d̪ur-gɔnd̪ʰo	দুর্গন্ধ	*stench*
20	dur-bʰɑg:o	আবেগ	*bad luck*	ɔ-bʰɑg:o	দুর্বেগ	*misfortune*
21	ɔ-ruʧi	অরুচি	*repugnance*	ku-ruʧi	কুরুচি	*garbage*
22	ku-mont̪ro	কুমন্ত্র	*bad advice*	ʃu-mont̪ro	সুমন্ত্র	*good advice*
23	dur-ɑʃɑ	দুরাশা	*groundless hope*	nir-ɑʃɑ	নিরাশা	*disappointment*
24	ʃu-biʧɑr	সুবিচার	*justice*	ɔ-biʧɑr	অবিচার	*injustice*
25	ʃu-gɔt̪o	সুগত	*avowed*	onu-gɔt̪o	অনুগত	*devoted*
26	ku-kɑʤ	কুকাজ	*miscreant*	ɔ-kɑʤ	অকাজ	*wrongdoing*
27	ɔpo-kɔrmo	অপকর্ম	*harm*	ku-kɔrmo	কুকর্ম	*sin*
28	ni- ʃid̪ʰ:o	নিষিদ্ধ	*profane*	pro-ʃid̪ʰ:o	প্রসিদ্ধ	*reverent*
29	ʃu-pɑt̪ro	সুপাত্র	*worthy person*	ku-pɑt̪ro	কুপাত্র	*unfit person*
30	ɔʃ-pɔrʃo	অস্পর্শ	*unwanted touch*	d̪uʃ-pɔrʃo	দুস্পর্শ	*rejected*
31	d̪ur-d̪riʃt̪o	দুরদৃষ্ট	*foresight*	ɔ-d̪riʃt̪o	অদৃষ্ট	*destiny*
32	ʃu-kʰɑd̪:o	সুখাদ্য	*delicacy*	ɔ-kʰɑd̪:o	অখাদ্য	*inedible food*

4. Experiment 4: test items for the suffixed ↔ suffixed (morphologically related) configuration

	Suffixed Items			Suffixed Items		
1	ʃok-ɑrt̪o	শোকার্ত	*mournful*	ʃok-ɑnːit̪o	শোকান্বিত	*saddened*
2	bʰɔe-purno	ভাপূর্ণ	*fearful*	bʰɔe-ʃunːo	ভয়শূন্য	*fearless*
3	bhokt̪i-hin	ভক্তিহীন	*godless*	bʰokt̪i-bʰɑb	ভক্তিভাব	*reverence*
4	ʃilp-okar	শিল্পকার	*artist*	ʃilp-i	শিল্পী	*artisan*
5	d̪ɔeɑɑ-lu	দয়ালু	*kind*	d̪ɔeɑ-hin	দয়াহীন	*selfish*
6	gæ̃n-i	জ্ঞানী	*knowledgeable*	gæ̃-t̪obbo	জ্ঞাতব্য	*knowledge*
7	gun-i	গুণী	*capability*	gun-onio	গুণনিও	*quality*
8	ʤɔl-ont̪o	জলন্ত	*scorched*	ʤɔl-ɔbʰɑb	জলাভাব	*barren*
9	lobʰ-i	লোভী	*greedy*	lobʰ-onio	লোভনীয়	*covetable*
10	loʤː-it̪o	লজ্জিত	*regretful*	lɔʤːɑ-bot̪i	লজ্জাবতী	*shameful*
11	mɑno-nijo	মাননীয়	*honourable*	mɑno-ʃik	মানসিক	*ethical*
12	ʃikʰː-it̪o	শিক্ষিত	*literary*	ʃikʰː-ɔk	শিক্ষক	*teacher*
13	t̪riʃ-it̪o	তৃষ্ণা	*thirsty*	t̪riʃ-ɑrt̪o	তৃষার্ত	*parched*
14	d̪ʰormo-hin	ধর্মহীন	*blasphemous*	d̪ʰɑrm-ik	ধার্মিক	*religious*
15	ɔspri-ʃt̪o	অস্পৃষ্ট	*intact*	ɔspri-ʃːo	অস্পৃশ্য	*untouchable*
16	ort̪ʰo-nit̪i	অর্থনীতি	*economy*	ort̪ʰo-ʃɑst̪ro	অর্থশাস্ত্র	*economics*
17	ɔʃʈɑ-ŋgo	অষ্টাঙ্গে	*the eight limbs*	ɔʃʈɑ-d̪ɔʃ	অষ্টাদশ	*eighteen*
18	kɑd̪ɑ-ʈe	কাদাটে	*dirty*	kɑd̪ɑ-moe	কাদাময়	*muddy*
19	guno-bɑn	গুণবান	*talented*	guno-moe	গুণময়	*quality*
20	gupt̪o-ʧɔr	গুপ্তচর	*spy*	gupt̪o-bʰɑb	গুপ্তভাব	*secretly*
21	guru-t̪ːo	গুরুত্ব	*importance*	guru-bʰɑb	গুরুভাব	*responsible*
22	ʧot̪ur-gun	চতুরগুণ	*quadruple*	ʧot̪ur-t̪ʰo	চতুরর্থ	*fourth*
23	ʧorit̪ro-hin	চরিত্রহীন	*depraved*	ʧorit̪ro-doʃ	চরিত্রদোষ	*character flaw*
24	ʧokʰːu-d̪ɑn	চক্ষুদান	*eyesight*	ʧakʰːu-ʃ	চাক্ষুষ	*visual*
25	ʧʰɑ̃ʈ-ɑno	ছাঁটানো	*cut off*	ʧʰɑ̃ʈ-ɑi	ছাঁটাই	*clipping*
26	ʤɔma-ʈ	জমাট	*coagulated*	ʤɔmɑ-no	জমানো	*amassed*
27	ʤɑt̪i-bʰrɔŋʃ o	জাতিভ্রংশ	*ethnicity*	ʤɑt̪i-hin	জাতিহীন	*stateless*
28	t̪oilo-kɑr	তৈলকার	*oily*	t̪oilo-ʤɔnt̪ro	তৈলজন্ত্র	*oil machine*
29	d̪ukʰːo-mɔe	দুঃখময়	*sad*	d̪ukʰː-i	দুঃখী	*distressed*
30	dʰɑrm-ik	ধার্মিক	*pious*	dʰɔrm-onaʃ	ধর্মনাশ	*annihilation*
31	pɑp-iʃʈʰo	পাপিষ্ট	*sinful*	pɑp-i	পাপী	*sinner*
32	prɑn-ɑnt̪o	প্রাণান্ত	*living*	prɑn-i	প্রাণী	*creature*

5. Experiment 5: test items for the prefixed ∼ suffixed (morphologically related) configuration

	Prefixed Items			Suffixed Items		
1	ɔpo-mɑn	অপমান	*dishonour*	mɑn-oniyo	মাননীয়	*honourable*
2	nir-gun	নির্গুণ	*void of qualities*	gun-i	গুণী	*wise person*
3	nir-bikɑr	নির্বিকার	*unconcerned*	biʧɑr-ɔk	বিচারক	*referee*
4	ɔ-ʤɑnɑ	অজানা	*unknown*	ʤɑnɑ-no	জানানো	*to make known*
5	ɔ-ʃuk^h	অসুখ	*unwell*	ʃuk^h-i	সুখী	*happy*
6	ɔ-biʃːɑʃ	অবিশ্বাস	*mistrust*	biʃːɑʃ-i	বিশ্বাসী	*dependable*
7	be-ɑin	বেআইন	*illegal*	ɑin-oto	আইনত	*legally*
8	ɔ-rup	অরূপ	*shapeless*	rup-ɑli	রুপালি	*shiny*
9	ɔ-d̪^{h}ɔrmo	অধর্ম	*unrighteous*	d̪^{h}ɑrm-ik	ধার্মিক	*righteous*
10	nir-d̪oʃ	নির্দোষ	*innocent*	d̪oʃ-i	দোষী	*guilty*
11	ɔ-biʧɑr	অবিচার	*injustice*	biʧɑr-ok	বিচারক	*judge*
12	ʃu-pɑt̪ro	সুপাত্র	*good prospective bridegroom*	pɑt̪r-i	পাত্রী	*prospective bride*
13	nir-loʤːo	নির্লজ্জ	*brazen*	loʤ-ito	লজ্জিত	*embarrassed*
14	ʃu-ʃɔŋbɑd	সুসংবাদ	*good news*	ʃɑŋbɑd̪-ik	সাংবাদিক	*journalist*
15	ɔ-gːæn	অজ্ঞান	*ignorant*	gæn-i	জ্ঞানী	*knowledgeable*
16	ɔnu-rɑg	অনুরাগ	*affinity*	rɑg-i	রাজী	*willing*

Data availability

OSF link

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