The effect of phonological and morphological overlap on the processing of Bengali words

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ABSTRACT

In normal language processing, we are continuously analyzing the form and structure of incoming speech signals in order to understand their meaning. At the same time, we unavoidably encounter situations in which words are contained within other words (e.g. *ham* in *hammer*). Since morphologically-related words often have a certain amount of phonological overlap, it is essential to understand the relevance of this overlap while investigating morphological processing. The current study provides a psycholinguistic investigation of the processing consequences of Bengali words overlapping in form both with and without being morphologically related. Overall, form-related items elicited significantly less priming than morphologically-related items. Form-related items differing in length by a single segment did not prime one another, while morphologically-related items did. However, form-related items matched in length but differing in a single segment did prime, indicating that relationships between form-related words are not always straightforward.

1 Introduction

In everyday language processing in most languages, we unavoidably encounter word-within-word situations; that is, where there is a certain degree of overlap between segments in words. Segments can overlap in a number of ways: they can overlap in form but not meaning (e.g. *tax* ~ *taxi*), or in both form and meaning (e.g. *write* ~ *writer*). This second case can be of several types: (i) identical consonants but different vowel quality e.g. *sing* ~ *sang*, *goose* ~ *geese*; (ii) identical consonants but different vowel length e.g. *meet* ~ *met*, *feed* ~ *fed*; (iii) identical vowels but different consonant length e.g. Bengali ফে'লো ~ ফেলল, [p^helo] ~ [p^helːo], 'throw-2FAM.FUT.IMP[1]' ~ 'throw-3.PST'; (iv) the addition of a final consonant e.g. *walk* ~ *walks*; (v) the addition of final vowel e.g. *hand* ~ *handy*; or (vi) the addition of a final vowel and a consonant e.g. *horse* ~ *horses*, *dine* ~ *diner*. While these examples only cover a small subset of such possibilities, it is clear that, in normal language processing, we frequently contend with situations where words that are not only related morphologically also exhibit an overlap in form.

It is therefore essential to understand the effect of phonological overlap when investigating morphological processing: namely, to what extent can the morphological effect be attributed to phonological overlap versus to morphological structure alone? Understanding the effect of phonological overlap can help to better answer the question of whether morphology should have a separate level of representation. Earlier research (cf. Rastle et al. 2000, Frost et al. 2000) has revealed that the effect of morphology cannot be attributed purely to semantic relatedness or phonological overlap. This suggests that morphological structure is an essential component in lexical organization, a notion that in turn has further implications for lexical access and processing (Frost & Grainger 2000).

When considering the processing of word forms, the following question arises: how much of the relatedness of words is linked to an overlap in form alone versus an overlap in both form and

[1] Abbreviations used: 1/2/3 = 1st/2nd/3rd person, ADJ = adjective, F = feminine, FAM = familiar, FUT = future tense, HON = honorific, IMP = imperative, INT = intimate, LOC = locative, M = masculine, N = noun, PRES = present tense, PST = past tense, VBN = verbal noun

morphology, particularly when the overlap constitutes a complete lexical item (e.g. *bull* ~ *BULLET*)? As we demonstrate in 1.1 below, although a substantial amount of research (cf. Amenta & Crepaldi 2012) has looked into the effect of phonological overlap, most studies employ embedded word priming[2] to address the question of whether a longer carrier word activates a shorter embedded word (e.g. *bullet* ~ *BULL*). Limited research has been carried out to investigate the opposite priming configuration, e.g. *bull* ~ *BULLET*, and those that do rarely employ real words as primes (e.g. *bull*).[3] Instead, the focus in these studies has predominantly been on whether segments activate form-related words (i.e. whether the segment [bʊ] can prime *BULL*). However, if there is a predicted difference in the direction of priming, it follows that both configurations should be examined using real-word primes. If words are represented in phonological form and this is how they are activated in the mental lexicon, then they will follow a particular phonological structure in the way they are produced.

In this study, we are concerned with the effect of full-word activation and priming in cases of direct form overlap. Word-within-word configurations exist in most languages and often, as the word length increases, the overlap also increases (whether meaningful or not). Word games are frequently developed on the basis of this element, e.g. the Japanese game 'Shiritori', in which one player must think of a word beginning with the final part of another player's previous word (e.g. トマト 'toma**to**' > トンカツ '**to**nkatsu'). The questions we ask are the following: first, will a longer word activate a shorter word if that shorter word is contained in the longer word? That is, once a full word (e.g. *hammer*) has been activated, do other candidates with phonological overlap (e.g. *ham*, *hammy*) remain viable, or are they deselected? Second, will a shorter word activate a longer one (e.g. *ham* ~ *HAMMER*)? Is the direction of priming crucial to activation?

In a strict Cohort Model analysis (cf. Marslen-Wilson 1987, 1990) and in purely phonological terms, an incoming speech signal activates words longer than the perceived signal: thus, on hearing *pen,* words such as *pen, pencil, penthouse* etc. will be activated. Once *pencil* has been recognized, however, any shorter words (e.g. *pen*) fall out of the cohort. Crucially, this phonological cohort effect does not hold for a morphological paradigm i.e. for word forms that all have the same stem, e.g. *cool, cooler, cooling.* While it could be likely that candidates remain activated if the item encountered first is a shorter word (e.g. *bull* ~ *BULLET*), there may be no remaining activation for the opposite configuration (e.g. *bullet* ~ *BULL*) because *bull* is no longer a viable candidate for the acoustic input. This issue is further complicated by the fact that it is often difficult to systematically compare the degree of phonological overlap between two conditions due to language internal phonological constraints.

Our third question asks, what is the effect of overlap in words that have equal length but differ by a final vowel (e.g. পরী ~ পোরা, [pori] ~ [porɑ], 'fairy' ~ 'fill.VBN' in Bengali)? Namely, how do overlapping phonological segments affect word recognition? Our final and overarching question is, are form-related words (e.g. *ham* ~ *HAMMER*) processed differently than words related in both form and morphology (e.g. *run* ~ *RUNNER*)? Ultimately, we want to understand the processing of underlying phonological priming effects and how it compares to that of morphological processing.

To investigate this, we conducted two sets of cross-modal[4] lexical decision experiments in Bengali. The reasons for using Bengali are two-fold: first, little has been done on the effect of phonological overlap in this language, which made even more interesting by the complexity of written forms. Secondly, in order to create balanced experimental conditions where segments (both vowels and consonants) could be added in a strictly controlled stepwise manner in both form-related **and** morphologically-related items, we needed a language which allows for the addition of individual

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[2] Such cases, where the target is embedded in the prime (*bullet* ~ *BULL*), have been widely referred to as "embedded word priming". In the current study, we are also investigating the priming configuration in which a prime word is embedded in a target (e.g. *bull* ~ *BULLET*). For this reason, we will use the terms LONG → SHORT to refer to embedded word priming and SHORT → LONG to refer to the opposite direction.

[3] Reasons for the LONG → SHORT preference are unclear from the literature but it is worth noting that this asymmetry in attention is also found in studies investigating the relationships between stems and affixes, where the majority of priming studies employ the affixed word → stem configuration (e.g. *helpful* ~ *HELP*, cf. Diependaele et al. 2011).

[4] Cross-modal designs present stimuli in different modalities, e.g. auditory primes and visual targets.

segments without concomitant changes in stress and vowel quality. While English does not allow for the creation of such a set of stimuli, Bengali does. As observed in examples given earlier, the language contains a large number of word pairs that exhibit identical segmental structure regardless of whether they are morphologically simple or complex. This is due to the fact that word stress in Bengali is fixed initially and morphological complexity does not lead to vowel reductions, e.g. কাল ~ কালি, [kɑl] ~ [kɑli], 'tomorrow' ~ 'ink' vs. নাক ~ নাকী, [nɑk] ~ [nɑk-i], 'nose' ~ 'nasal'.

The first set of experiments in this study (1a, 1b, and 1c) examined the relationships between three different types of solely phonologically-related pairs (e.g. কাল ~ কালি, [kɑl] ~ [kɑli], 'yesterday' ~ 'ink'), and the second set (2a, 2b, and 2c) examined the relationship between three types of morphologically-related pairs (e.g. দাগ ~ দাগী, [d̪ɑg] ~ [d̪ɑg-i], 'mark, stain' ~ 'mark-ADJ, stained'). Within these sets of experiments, we manipulated the priming configurations systematically by examining the addition/deletion of one vowel (CVC ~ CVCV), the addition/deletion of one consonant (CVCV ~ CVCVC), or a change of final vowel ($CVCV_1$ ~ $CVCV_2$). This stepwise examination was done to maintain as much homogeneity as possible between the stimuli, as well as to facilitate an examination of the effect of priming direction (i.e. whether LONG → SHORT primed significantly more than SHORT → LONG). We also manipulated syllable structures systematically, designing comparable experiment conditions for both the phonologically-related and morphologically-related pairs.

Before presenting our findings, it is necessary to consider the existing literature on the effect of direct phonological priming (as opposed to mediated/semantic priming) with word primes (as opposed to pseudo-word primes or segment of a word). Section 1.1.1 presents studies investigating the LONG → SHORT priming configuration, as this is where the majority of evidence for form overlap is found. Section 1.1.2 discusses studies employing the SHORT → LONG configuration, and Section 1.1.3 provides a summary of tasks in which the stimuli have overlapping segments.

1.1 Phonological priming

The main focus in this section is on studies where the prime or target is a completely embedded word; nevertheless, some studies which investigated partial form overlap are included. There is also substantial literature on the effect of rhyme priming (e.g. Praamstra et al. 1994, Bölte & Coenen 2002) which is not listed here (but see Zwisterlood 1986, Radeau et al. 1995, and Dufour 2008 for comprehensive reviews; see also Zhang & Samuel 2015 for a review of embedded word priming).

1.1.1 Is there a *bull* in *bullet*? (LONG → SHORT priming)

As shown in Table 1, the favored priming configuration in studies examining phonological overlap between full words priming is the LONG → SHORT configuration (e.g. *bullet* ~ *BULL*). Jakimik et al. (1985) found that words sharing both orthographic and phonological segments (e.g. *message* ~ *MESS*) primed in an auditory–auditory configuration and, more recently, Zhang & Samuel (2015) reported analogous findings using a similar paradigm. In their study, Zhang & Samuel (2015) further manipulated the proportion of overlap between the prime and the target, and found that the degree of the priming increased with the proportion of overlap between the prime and the target: e.g. a combination which had a 2/3 syllable match (e.g. *property* ~ *PROPER*) showed a stronger priming effect than pairs which had a 1/2 syllable match (e.g. *hamster* ~ *HAM*).

There are also studies that fail to find such an effect. Although words sharing both orthographic and phonological segments primed, Jakimik et al. (1985) did not find priming for word pairs that only shared initial phonological segments (e.g. *definite* ~ *DEAF*) or initial orthographic segments (*legislature* ~ *LEG*). In a cross-modal experiment employing word pairs such as *bullet* ~ *BULL*, Marslen-Wilson et al. (1994) also found no priming; if anything, an inhibition effect was observed.[5]

[5] Aside from the fact that this study was presented cross-modally, it is worth noting that the phonologically-related words were interspersed with trials in which word pairs also shared morphological relationships. Thus, for some of the trials, both semantic and phonological relationships were present whereas in other trials, primes and targets were only phonologically related. Accordingly, it is difficult to tease apart what precisely drove the priming effect.

Study	**Direction**	**Example**	**Finding**	**Modality**
Jakimik et al. (1985)	L > S	*message ~ MESS* *definite ~ DEAF* *legislature ~ LEG*	priming no priming no priming	auditory intramodal
Marslen-Wilson et al. (1994)	L > S	*bulletin ~ BULLET*	no priming	cross-modal
Vroomen & de Gelder (1997)	L > S	*velg ~ VEL* *(Du. 'rim' ~ 'skin')*	no priming[6]	cross-modal
Zhang & Samuel (2015)	L > S	*property ~ PROPER* *brownie ~ BROWN* *studio ~ STEW*	priming priming priming	auditory intramodal
Marslen-Wilson (1990)	S > L (early prime) N/A	*[dɔ] ~ DOG* *feel ~ FEED*	priming inhibition	cross-modal
Spinelli et al. (2001)	S > L N/A	*ver ~ VERTIGE* *(Fr. 'worm' ~ 'vertigo')* *verger ~ VERTIGE* *(Fr. 'orchard' ~ 'vertigo')*	priming no priming	auditory intramodal and cross-modal
Dufour & Peereman (2003)	S > L N/A	*cou ~ COULISSE* *(Fr. 'neck' ~ 'slide')* *couture ~ COULISSE* *(Fr. 'sewing' ~ 'slide')*	priming no priming	auditory intramodal (shadowing)
Friedrich et al. (2013)	S > L	*[ano] ~ ANORAK* *[ana]~ ANORAK*	priming no priming[7]	cross-modal and ERP
Radeau et al. (1989)	2 segment overlap 1 segment overlap	*palais ~ PARURE* *(Fr. 'palace' ~ 'set')* *poulet ~ PARURE* *(Fr. 'chicken' ~ 'set')*	inhibition inhibition	auditory intramodal
Goldinger et al. (1992)	N/A	*bang ~ BONE*	priming	auditory intramodal (shadowing)
Slowiaczek & Hamburger (1992)	3 segment overlap 2 segment overlap 1 segment overlap	*stiff ~ STILL* *steep ~ STILL* *smoke ~ STILL*	inhibition no priming no priming	auditory and visual intramodal
Praamstra et al. (1994)	N/A	*beeld ~ BEEST* *(Du. 'statue' ~ 'animal')*	no priming	auditory intramodal
Radeau et al. (1995)	N/A	*pote ~ POCHE* *(Fr. 'mate' ~ 'poached')*	no priming	auditory intramodal
Dufour & Peereman (2003)	'high' lexical cohort 'low' lexical cohort	*banque ~ BANDE* *(Fr. 'bank' ~ 'band')* *batte ~ BASE* *(Fr. 'bat' ~ 'base')*	inhibition no priming	auditory intramodal
McQueen & Sereno (2005)	N/A	*zeep ~ ZOON* *(Du. 'soap' ~ 'son')* *knak ~ KNAP* *(Du. 'snap' ~ 'handsome')*	no priming priming	auditory intramodal
Dufour et al. (2007)	N/A	*moule ~ MOUCHE* *(Fr. 'mussel' ~ 'fly')*	inhibition	auditory intramodal
Dufour & Peereman (2009)	4 segment overlap 3 segment overlap 2 segment overlap	*canal ~ CANARD* *(Fr. 'canal' ~ 'duck')* *crème ~ CRÈCHE* *(Fr. 'cream' ~ 'nursery')* *crème ~ CRASSE* *(Fr. 'cream' ~ 'dirt')*	inhibition inhibition no priming	auditory intramodal

Table 1. Overview of previous priming studies examining phonological overlap (divided into LONG → SHORT (L > S), SHORT → LONG (S > L), and segment overlap in chronological order).

6 In the same study, a priming effect was reported when a nonword prime was used.
7 There was "a trend" (p = .05) towards inhibition.

1.1.2 Priming *bullet* with *bull* (SHORT → LONG priming)

Limited research has been carried out to investigate the SHORT → LONG priming configuration for form-related words: i.e. whether a shorter phonological form activates a longer one (e.g. *bull* ~ *BULLET*). In one of the most well-known studies of phonological overlap, Zwitserlood (1989) and Zwitserlood & Schiefers (1995) found that Dutch word segments (e.g. [kapit]) auditorily primed words that shared the same initial disyllabic sequence (e.g. *kapitein* 'captain' and *kapitaal* 'financial capital') as well as semantically-related targets (e.g. *schip* 'ship', semantically related to 'captain' and *geld* 'money', related to *kapitaal* 'financial capital'). Once the auditory prime included a final vowel, e.g. [kapitɛɪ], only *schip* 'ship' was activated and primed; *geld* 'money' was not, as the vowel [aː] in the word *kapitaal* no longer matched the auditory input. These findings have had crucial implications for theories regarding the perception of a spoken word, particularly with regards to the effect of cohort competitors during lexical processing.

However, attention must be drawn to the fact that the primes in these experiments were word segments, not words in their own right.[8] In Marslen-Wilson's seminal work (Marslen-Wilson & Welsh 1978, Marslen-Wilson 1987), findings suggest that perception of a partial string of phonemes is sufficient to activate longer lexical items; e.g. hearing the string [bæt] will activate the words *batter* or *battle*. A further study investigating the effect of partial initial form overlap (Marslen-Wilson 1990) found that hearing the segment [dɔ] facilitated the speed of lexical decision on the visual probe *dog*, whereas hearing *dock* resulted in no priming effect. To what extent this effect can be extended to direct phonological overlap remains unclear, as the mapping between phonological and semantic representation does not occur on a one-to-one basis (cf. Bölte & Coenen 2002).

In one of the few studies employing real word primes, Spinelli et al. (2001) found facilitation for French word pairs that shared initial segments (e.g. *ver* ~ *VERTIGE*, 'worm' ~ 'vertigo'). This effect was present in both auditory intramodal and cross-modal (auditory–visual) modalities.[9] However, when an initial overlap of segments occurred in a disyllabic prime (e.g. *verger* ~ *VERTIGE*, 'orchard' ~ 'vertigo'), this facilitation disappeared.

1.1.3 Overlapping segments in form priming

In studies where the number of phonological segments in prime and target words were uniform (e.g. *stiff* ~ *still*), most reported no priming or inhibition. These findings are in line with theories of lexical competition, which assume mismatch due to the fact that the primes are not fully embedded in the targets. Marslen-Wilson (1990) reported inhibition for English word pairs such as *feel* ~ *FEED* in the auditory–visual modality, and this was replicated both in cross-modal and auditory intramodal conditions in Slowiaczek and Hamburger (1992). Inhibition was also found for French word pairs such as *crème* ~ *CRÈCHE*, 'cream' ~ 'nursery' (Dufour & Peereman 2009), *moule* ~ *MOUCHE*, 'mussel' ~ 'fly' (Dufour et al. 2007), and a lack of priming was found for pairs such as *pote* ~ *POCHE*, 'mate' ~ 'poached' (Radeau et al. 1995). The difference between word pairs that fail to prime and those that produce inhibition has been ascribed to the number of overlapping segments (cf. Radeau et al. 1989, Slowiaczek & Hamburger 1992, Dufour & Peereman 2009) as well as number of lexical competitors (cf. Dufour & Peereman 2003).

Thus, three key points can be drawn from the previous evidence presented above. First, many of the previous studies only used monosyllabic word pairs as their stimuli, meaning that the effect of syllabification on an overlap in form has not yet been thoroughly investigated. Secondly, there is a distinct difference between patterns of facilitations for items with form overlap depending on whether a cross-modal or intra-modal paradigm is used: this may reflect the effects of modality-specific versus modality-independent processing. Finally, both lexical status of the prime (that is, whether it is a segment or a full word in its own right) and the direction of presentation (SHORT →

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[8] Furthermore, targets were associatively/semantically related to the input signal.

[9] Interestingly, final overlap pairs (e.g., French *tige* ~ *PRESTIGE,* 'stem ~ prestige') only generated significant priming effects in the auditory–auditory modality; when presented in cross-modal conditions, these items did not prime one another.

LONG VS. LONG → SHORT) may affect processing due to differences in cohort competition. These points have been considered in the present study and the lack of systematic investigation of some of the aspects above have motivated our experimental design.

1.2 Questions and hypotheses

Our study is concerned with the role of phonological priming and how it relates to morphological processing. To this end, we conducted two sets of cross-modal lexical decision experiments. In first set (Experiments 1a–1c), stimuli consisted of three different types of monomorphemic, phonologically-related Bengali word pairs (e.g. কাল ~ কালি, [kɑl] ~ [kɑli], 'yesterday' ~ 'ink'), while three types of morphologically-related Bengali stimuli (e.g. দাগ ~ দাগী, [d̪ɑg] ~ [d̪ɑg-i], 'mark, stain' ~ 'mark-ADJ, stained') were used in Experiments 2a–2c. We chose to employ auditory–visual cross-modal priming in order to investigate the activation of modality-independent lexical representations. If prime and target are presented in the same modality, any effect might be subject to the influence of modality-specific memory traces or episodic memory. In addition, the use of cross-modal priming avoids further complications caused by orthographic factors, which can also affect the degree of phonological priming (cf. Ferrand & Grainger 1994).

In this study, we raised three related questions. First, will phonologically-related sequences activate one another? Findings for priming in phonologically-related word pairs are incongruent: as we saw in Section 1.1, some studies find priming for form-related words while others find none (cf. Marslen-Wilson et al. 1994 and Zhang & Samuel 2015). In pure form priming, the semantics of the target will not match the input semantics (e.g. *bat ~ BATTLE*). Hence, it is possible that phonological overlap alone is insufficient to achieve facilitation, or if any activation does occur, this is subsequently blocked due to phonological competitors. If this is the case, we predict that we will find no priming effect for our form-related conditions.

Our second question is based on the order of presentation of the stimuli; namely, will a shorter word activate a longer one as the Cohort Model predicts, or will a longer word activate the shorter? Is the direction of priming crucial to activation? To address this question, we presented stimulus pairs in both orders (SHORT → LONG and LONG → SHORT) in those experiments where the pairs differ in the number of segments. Thus, each member of a stimulus pair was used as prime and target to establish whether the order of presentation affects facilitation.

As discussed above, most research has followed the pattern of presenting the complex item as the prime and the simple(r) item as the target (i.e. the LONG → SHORT configuration, *bullet ~ BULL*). These studies have elicited disparate results: some find priming while others do not (cf. Jakimik et al. 1985, Marslen-Wilson et al. 1994, Zhang & Samuel 2015). In the few studies that employ the SHORT → LONG configuration (e.g. *mess ~ MESSAGE*), priming effects have been observed between segments and full word forms in mediated priming (cf. Zwitserlood 1989, Zwitserlood & Schriefers 1995, Marslen-Wilson 1990). This has led to the hypothesis that, in hearing a segment of a word (e.g. [bæ]), the cohort is activated and related lexical representations (e.g. *bad, back, bat*) are accessed along with related semantic information. Therefore, when the semantic target is consistent with the auditory stimulus (e.g. [bæ] ~ *AWFUL*), a priming effect will be observed.

However, if there is merely a form relationship between items, a longer item which constitutes a real word may not activate a phonologically-related shorter item since, according to models such as the Cohort Model, the shorter item is no longer a competitor and would have fallen out of the cohort. That is, *bullet*, for instance, could still be extended to *bulletin* but once *bulletin* has been heard, *bullet* is no longer in contention. If Cohort Model predictions are borne out, we may see facilitation in the SHORT → LONG form-related conditions but none in the LONG → SHORT form-related conditions. And while we expect strong facilitation for all morphologically-related pairs, there may be a difference in the degree of priming between the two orders of presentation.

Our third question focuses on the difference between phonologically- and morphologically-related words: using precisely the same structural overlap, does the introduction of a semantic relationship result in priming and does this depend on the type of stimulus? To examine this, we selected morphologically-related words which were also semantically related, with segmental structures parallel to those in the purely phonologically-related condition. Following a wealth of evidence for the priming of morphologically-related words (cf. Marslen-Wilson et al. 1994), we expect to observe a priming effect for all configurations in Experiments 2a–2c.

2 Experiments 1a–1c: Form priming

The first set of experiments investigates the relationship between phonologically-related Bengali word pairs that differ in a single segment. Below we present the findings from three types of word pairs that involved either the addition/deletion of one vowel (Experiment 1a: CVC ~ CVCV), the addition/deletion of one consonant (Experiment 1b: CVCV ~ CVCVC), or a change of a final vowel (Experiment 1c: $CVCV_1 \sim CVCV_2$). For the types where the prime and target differ in word length (i.e. Experiments 1a–1b), we also investigated the effect of directionality; that is, whether short words will prime longer words (e.g. কাল ~ কালি, [kɑl] ~ [kɑli], 'yesterday' ~ 'ink'), or if employing longer words as primes (কালি ~ কাল, [kɑli] ~ [kɑl], 'ink' ~ 'yesterday') will result in a different pattern of facilitation.

2.1 Method

2.1.1 Participants

64 Bengali native speakers took part in this set of experiments. All participants were undergraduate students at Jadavpur University and Bethune College, Kolkata University, in Kolkata, India. None of the participants reported either hearing difficulties or dyslexia and all subjects were compensated accordingly for their participation.

2.1.2 Materials

In this experiment, the stimuli were comprised of either monomorphemic nouns or adjectives. In terms of their structure, three different types of word pairs were used (Table 2). In the first type (CVC ~ CVCV), the prime and the target differed by the addition of a final vowel. This also resulted in a difference in the number of syllables: CVC. ~ CV.CV. In second type (CVCV ~ CVCVC), prime and target differed by a consonant with the number of syllables remaining constant, but a change in the type of syllable (open vs. closed syllable) was introduced (CV.CV ~ CV.CVC). In the $CVCV_1 \sim CVCV_2$ type, the number and the type of syllable remained the same (CV.CV) but the final vowel was different. The full stimulus lists for Experiments 1a–1c are found in Appendix A.

32 test pairs were selected for each type. All words were morphologically simple and thus each word pair was related only in form. In addition, 16 control words and 32 pseudo-word pairs with matching syllable structure were chosen for each type. Half of the pseudo-word pairs were related in form and the other half were unrelated. Primes were always real words.

Condition	**CVC ↔[10] CVCV**	**CVCV ↔ CVCVC**	**$CVCV_1$ ↔ $CVCV_2$**
Critical word pair (gloss)	kɑl ↔ kɑli *yesterday ↔ ink*	ɖɑli ↔ ɖɑlim *basket ↔ pomegranate*	d̪ɑbi ↔ d̪ɑbɑ *claim ↔ chess*
Pseudo-word (gloss)	keʃ → *koʃɑ *hair → –*	nit̪i → *nit̪ik *law → –*	mɑne → *mɑnu *meaning → –*

Table 2. Sample word pairs used in Experiments 1a–1c (form priming).

2.1.3 Recording

Auditory stimuli were recorded by a female native speaker of Bengali in a sound-attenuated room, using the software Audacity with a Roland R-26 WAV recorder at a sampling rate of 44.1kHz. The auditory stimuli were then extracted using the acoustic analysis software PRAAT (Boersma & Weenink 2011). The volume of all items was equalized.

[10] Note: the double arrow '↔' in the table indicates testing in both directions.

2.1.4 Design

There were two within subject factors: *Relatedness* (i.e. whether the prime and the target are related or unrelated) and *Direction* of priming (i.e. whether the prime was the shorter or longer word). Table 3 provides an example of the design for the CVC ~ CVCV type. The CVCV ~ CVCVC type followed an identical design. A Latin-Square design was used to create four lists: in each list, each word pair appeared only once. Each list contained equal numbers of all four conditions with equal number of trials. All visual targets appeared only once. As shown in Table 3, for each critical stimuli pair, each word served as the target twice, paired once with a related prime and once with an unrelated prime. Experiments 1a–1c were always run first as we wanted to avoid the spreading of a possible effect of the morphologically rich stimulus set in Experiments 2a–2c which may have led to an inflation of the form priming effect.

List	Prime	Target	Direction	Relatedness
List 1	kɑl ‘yesterday’	kɑli ‘ink’	SHORT → LONG	related
List 2	d̪oʃ ‘mistake’	kɑli ‘ink’	SHORT → LONG	unrelated
List 3	kɑli ‘ink’	kɑl ‘yesterday’	LONG → SHORT	related
List 4	kẽʧo ‘snail’	kɑl ‘yesterday’	LONG → SHORT	unrelated

Table 3. Sample design of the CVC ~ CVCV type for pure form priming.

For the $CVCV_1 \sim CVCV_2$ type, four lists were created in a similar manner. Here, *Direction* was not relevant as the items were of the same length. Thus, only *Relatedness* was coded (Table 4).

List	Prime	Target	Direction	Relatedness
List 1	d̪ɑbi ‘claim’	d̪ɑbɑ ‘chess’	N/A	related
List 2	ʧʰɑpɑ ‘print’	d̪ɑbɑ ‘chess’	N/A	unrelated
List 3	d̪ɑbɑ ‘chess’	d̪ɑbi ‘claim’	N/A	related
List 4	ʃiʃi ‘bottle’	d̪ɑbi ‘claim’	N/A	unrelated

Table 4. Sample design of the experiment $CVCV_1 \sim CVCV_2$ for pure form priming.

Previous research suggests that strategic processing may bias responses in a phonological priming paradigm (cf. Radeau et al. 1989, Goldinger et al. 1992, Dufour 2008). Therefore, to reduce the likelihood of predictive responses by strategy, all three prime-target types were combined into a comprehensive sequence, e.g. List 1 of CVC ~ CVCV, CVCV ~ CVCVC, and $CVCV_1 \sim CVCV_2$ were combined into one list. This was done so as to avoid prediction of the syllable structure of the target. Four combined lists were created in total. The order within each list was pseudo-randomized with the constraint that no more than four consecutive trials required the same lexical-decision response or were of the same syllable type.

2.1.5 Procedure

The experiment started with a practice task of ten trials. This practice task was repeated until the experimenters were satisfied that the task was understood. Then each group of participants completed one list of the phonological priming sequence (ca. 8min) and, after a break, they completed one list of a second unrelated experiment (again ca. 8min). The stimuli were presented with experimental software developed by Reetz & Kleinmann (2008). Each trial started with a ‘beep’ tone. The auditory primes were played through closed-ear headphones (Sennheiser PX200) 200ms after the offset of the beep. Visual targets in Bengali regular font were then displayed for 800ms immediately at the offset of the auditory primes. The inter-trial interval was 1500ms. Participants were instructed to make a lexical decision on the visual target as quickly and as accurately as possible. Reaction time was measured from the onset of stimulus display.

2.1.6 Data cleaning and analysis

The data cleaning and analysis procedures were the same for all three experiments (N = 12277) reported here. Items and participants with less than 60% accuracy were excluded: this resulted in a loss of 13.9% of the data (1707 data points). In addition, to enhance the normality of the RT distribution, RT of less than 200ms and those above/below two standard deviations of each participant were excluded. This resulted in a further loss of 5.7% of data (620 data points).

Statistical analyses were performed by fitting a linear mixed-effects model to reaction times (RTs). Using the lmer function from the lme4 package, RTs were modeled as a function of the main fixed effect factors, *Relatedness* and (where applicable) *Direction*. These fixed effects were sum-coded. Goodness of fit was established by model comparison and normality of residuals. Following Baayen et al. (2008), all t-values greater than 2 or less than -2 were treated as significant. Subjects and Items were treated as random factors.

We are aware of the suggestion that the random effect structure should be kept maximal (Barr et al. 2013) and thus 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 (Bates et al. 2015, Matuschek et al. 2017). A likelihood ratio test (LRT) is used to test whether reducing the random effect harms the model fit. αLRT = 0.2 is used which gives more weight to more complex models (Matuschek et al. 2017).

2.2 Results

We next report on the findings for each word-pair type.

2.2.1 Experiment 1a: CVC ~ CVCV

Experiment 1a tested the relationship between phonologically-related word pairs that differed in the presence/absence of a final vowel. In an analysis containing both fixed effects[11], neither *Relatedness* (Est. = 3.59, SE = 3.42, t = 1.05) nor *Direction* (Est. = 1.85, SE = 5.99, t = 0.31) showed a significant effect on RT. Following this, the optimal model[12] for this data was the null model. This was confirmed in model comparison, where there was no significant difference between the null model and a model containing either *Relatedness* ($\chi^2(1) = 1.64$, p = 0.20) or *Direction* ($\chi^2(1) = 0.11$, p = 0.74).

This experiment elicited no effect of *Relatedness* on RT; that is, RTs to the form related condition (e.g. কাল ~ কালি, [kɑl] ~ [kɑli], 'yesterday' ~ 'ink') were no faster than those for the unrelated condition (ধান ~ কালি, [d̪ʱɑn] ~ [kɑli], 'rice grain' ~ 'ink'). Likewise, there was no effect of *Direction*: RTs for the SHORT → LONG priming direction (e.g. কাল ~ কালি, [kɑl] ~ [kɑli], 'yesterday ~ ink') were no faster than those for the LONG → SHORT direction (e.g. কালি ~ কাল, [kɑli] ~ [kɑl], 'ink' ~ 'yesterday') (Table 5). An error analysis indicated no interaction between *Relatedness* and error ($\chi^2(1) = 0.20$, p = 0.67), nor were errors significantly different between the two directions of priming, ($\chi^2(1) = 0.54$, p = 0.46).

Direction	Related RT	Related SE	Control RT	Control SE	Effect (in ms.)
SHORT → LONG (CVC ~ CVCV)	591	14.4	601	14.5	10
LONG → SHORT (CVCV ~ CVC)	589	14.3	604	14.2	15

Table 5. Mean reaction times (in ms) for Experiment 1a (N = 1590).

2.2.2 Experiment 1b: CVCV ~ CVCVC

Experiment 1b tested the relationship between phonologically-related word pairs that differed in the

[11] ReacTime~Relatedness +Direction+ (1 +Relatedness|Date.Time.SJ) + (1 |Target))
[12] ReacTime~1 + (1 |Date.Time.SJ) + (1 |Target))

presence/absence of a final consonant. In an analysis containing the fixed effects[13], neither *Relatedness* (Est. = 1.76, SE = 2.89, t = 0.63) nor *Direction* (Est. = -3.50, SE = 6.18, t = -0.57) showed a significant effect on RTs. Following this, the optimal model for this data was the null model.[14] This was confirmed through model comparison, where there was no significant difference between the null model and a model containing either *Relatedness* ($\chi^2(1) = 0.50$, p = 0.48) or *Direction* ($\chi^2(1) = 0.31$, p = 0.58).

The model showed no effect of prime on RTs; that is, RTs to the form-related condition (e.g. বাটি ~ বাটিক, [bɑʈi] ~ [bɑʈik], 'bowl' ~ 'wax dye') were no faster than those for the unrelated condition (বাটি ~ কুমির, [bɑʈi] ~ [kumir], 'bowl' ~ 'crocodile'). Likewise, there was no effect of *Direction*: RTs for the SHORT → LONG direction (বাটি ~ বাটিক, [bɑʈi] ~ [bɑʈik], 'bowl' ~ 'wax dye') were no faster than for the LONG → SHORT direction (বাটিক ~ বাটি, [bɑʈik] ~ [bɑʈi], 'wax dye' ~ 'bowl').

Direction	**Related**		**Control**		**Effect**
	RT	**SE**	**RT**	**SE**	**(in ms.)**
SHORT → LONG (CVCV ~ CVCVC)	607	14.3	609	14.3	-2
LONG → SHORT (CVCVC ~ CVCV)	605	14.4	596	14.4	9

Table 6. Mean reaction times (in ms) for Experiment 1b (N = 1478).

2.2.3 Experiment 1c: $CVCV_1 \sim CVCV_2$

Experiment 1c tested the relationship between phonologically-related word pairs that differed in change of a final vowel. For this priming configuration, only one fixed effect was relevant: *Relatedness*. The optimal model[15] contained *Relatedness* as a significant fixed effect (Est. = 25.63, SE = 9.53, t = -2.69), random slopes and intercepts between *Relatedness* and subjects, and random slopes and intercepts between *Relatedness* and targets. Reducing *Relatedness* from the model structure significantly affected goodness of fit ($\chi^2(5) = 54.94$, p < .0001*). Therefore, *Relatedness* was a significant predictor. This model appeared homoscedastic when inspected visually. In this analysis, we found a significant priming effect of *Relatedness*: RTs for the form-related condition (e.g. পরি ~ পোরা, [pori] ~ [porɑ], 'fairy' ~ 'fill.VBN') were on average 23ms faster than those for the unrelated condition (e.g. তুলি ~ পোরা, [t̪uli] ~ [porɑ], 'brush' ~ 'fill.VBN').

	Related		**Control**		**Effect**
	RT	**SE**	**RT**	**SE**	**(in ms.)**
$CVCV_1 \sim CVCV_2$	595	11.6	618	11.6	23*

Table 7. Mean reaction times (in ms) for Experiment 1c (N = 1461).

2.3 Discussion

The first set of experiments tested the effect of pure phonological overlap in cross-modal priming in three different pairs of phonologically-related Bengali words. In Experiment 1a, the prime and the target differed by the presence/absence of a final vowel (e.g. কাল ~ কালি, [kɑl] ~ [kɑli], 'yesterday' ~ 'ink'). In Experiment 1b, prime and target differed by the presence/absence of a final consonant (বাটি ~ বাটিক, [bɑʈi] ~ [bɑʈik], 'bowl' ~ 'wax dye'). In Experiment 1c, the word pairs differed in final vowel quality (পরি ~ পোরা, [pori] ~ [porɑ], 'fairy' ~ 'fill.VBN'). We examined not only the relationship between the pairs, but also whether directionality of priming affected this relationship.

There has been much discussion about the contribution of overlapping phonological segments to the inhibition of priming (cf. Slowiaczek & Hamburger 1992, Praamstra et al. 1994, Dufour &

[13] ReacTime~Relatedness +Direction+ (1+Relatedness|Date.Time.SJ) + (1 |Target)
[14] ReacTime~1 + (1 |Date.Time.SJ) + (1 |Target))
[15] ReacTime~Relatedness + (1+Relatedness|Date.Time.SJ) + (1+Relatedness|Target)

Peereman 2003, 2009).[16] It has been suggested that the inhibitory effect grows as the number of overlapping segments grows. Thus, as the number of initial shared segments increases so does the competition, resulting in a lack of priming for words such as *steep* ~ *STILL* and inhibition for words such as *stiff* ~ *STILL* in Slowiaczek and Hamburger (1992). Evidence from recent masked priming and eye-tracking studies also supports the existence of such an inhibition effect (cf. Frisson et al. 2014a, 2014b).

In Experiments 1a and 1b, where word length differed by a single segment, no priming effect was observed. In addition, there was no interaction between *Relatedness* and *Direction* in either experiment, indicating a lack of priming for both LONG → SHORT and SHORT → LONG configurations. In Experiment 1c, where the word length of the prime and target were the same (e.g. পরি ~ পোরা, [pori] ~ [porɑ], 'fairy' ~ 'fill.VBN'), a significant priming effect was observed. We first discuss the findings related to the experiments in which word length differed, i.e. SHORT → LONG and LONG → SHORT configurations (Experiments 1a and 1b).

2.3.1 Findings for SHORT → LONG priming configurations

As discussed in Section 1.1, the phonological priming literature has largely focused on the LONG → SHORT configuration. Little is known concerning the reverse configuration: SHORT → LONG. In the experiments which examined direction of priming (Experiments 1a and 1b), we found no priming for either configuration, whether consisting of the addition of a vocalic segment in Experiment 1a (CVC ~ CVCV) or a consonantal segment in Experiment 1b (CVCV ~ CVCVC). At first glance, this finding is contradictory to the predictions made by most speech recognition models (e.g. Cohort) as hearing shorter words should, in theory, activate a cohort of words which begin with those segments (cf. Zwitserlood 1989, Zwitserlood & Schriefers 1995, Marslen-Wilson 1990). However, the current experiment deviated from previous studies in several ways: 1) our targets did not share semantic information with the primes, 2) the visual targets were very close in form to the auditory primes (e.g. বাটি ~ বাটিক, [bɑt̪i] ~ [bɑt̪ik], 'bowl' ~ 'wax dye'), and 3) the primes were real words. This third factor, in particular, conceivably causes strong lexical competition. Word fragments such as [dɔ] are incomplete and unspecified: they are neither a real word, nor do they have a distinctive meaning. Therefore, the likelihood that they will activate lexical competitors sharing the same initial segments (e.g. *dog* or *dock*) is much higher than a prime [dɔg], which initiates a mismatch for many items sharing initial segments (other than longer words such as *doghouse* or *doggy*). Furthermore, a full-word prime (*dog*) activates associated semantic information that will presumably mismatch with that of *dock.* As discussed above, evidence for full word priming is scant.[17]

2.3.2 Findings for LONG → SHORT priming configurations

No priming effect was observed for the LONG → SHORT condition, either for the CVCV ~ CVC type (কালি ~ কাল, [kɑli] ~ [kɑl], 'ink' ~ 'yesterday') or the CVCVC ~ CVCV type (বাটিক ~ বাটি, [bɑt̪ik] ~ [bɑt̪i], 'wax dye' ~ 'bowl'). This finding agrees with predictions made by models such as the Cohort model: when the prime is the longer form (e.g. কালি, [kɑli], 'ink'), any shorter forms (e.g. কাল, [kɑl], 'yesterday') should theoretically be excluded from the cohort. However not all findings suggest inhibition: recall that Jakimik et al. (1985) and Zhang & Samuel (2015) found priming for configurations in which a longer word was presented as prime, e.g. *message* ~ *MESS* and *property* ~ *PROPER.* Zhang & Samuel (2015) attributed this finding to their use of the auditory–auditory

[16] In addition to lexical competition effects, it has been widely suggested (cf. Goldinger 1999, Pitt & Shoaf 2002) that inhibition between phonological pairs sharing segments could also be attributed to task effects; that is, participants developing anticipatory responses to the word pairs.

[17] A notable exception is the *ver* ~ *VERTIGE* 'worm ~ vertigo' pairs in Spinelli et al. (2001), which elicited strong priming in both auditory–auditory and cross-modal conditions. However, it is worth noting here that the targets in these experiments actually contained two embedded words (e.g. *CRITIQUE* which contains both *cri* 'shout' and *tique* 'tick'); this was done in order to measure effects of phonological overlap of both initial and final segments.

priming paradigm, and suggested that intramodal auditory conditions induce more sensitivity to words embedded initially (e.g. ***proper**ty)*. Correspondingly, our finding mirrors those found in other cross-modal experiments in Marslen-Wilson et al. (1994) and Vroomen & de Gelder (1997): hearing a word that contains a longer embedded word (e.g. *bullet*) will not facilitate responses to a shorter target word, even though it exists within the prime word (e.g. *bull*).

2.3.3 Findings for final segment mismatch

Finally, we observed a significant priming effect for word pairs that differed in final vowel in Experiment 1c ($CVCV_1 \sim CVCV_2$, e.g. পরি ~ পোরা, [pori] ~ [porɑ], 'fairy' ~ 'fill.VBN'). This was perhaps the most surprising finding of all, as the majority of similar studies usually result in either inhibition or a lack of priming (cf. Radeau et al. 1989, Slowiaczek & Hamburger 1992, and Dufour & Peereman 2003, 2009). One notable exception is found in McQueen & Sereno (2005), who found that Dutch word pairs differing in a final consonant (e.g. *knak* ~ *knap*, 'snap' ~ 'handsome') induced priming. We have attributed the lack of priming in Experiments 1a and 1b to effects of real-word primes and cross-modal priming paradigm; however, Experiment 1c was conducted with the same stimuli in the same conditions. What, then, could be driving these results?

Syllabic influences have been shown to be important in word priming (cf. Emmorey 1989, Dumay & Content 2012). Ferrand & Grainger (1996) found that word pairs in which syllable structure was matched in the initial syllable (e.g. French *ba.lade* ~ *ba.lance,* 'ride' ~ 'balance') elicited significantly faster naming latencies than word pairs exhibiting syllable mismatch (e.g. *ba.lade* ~ *bal.con*, 'ride ~ balcony'). As Vroomen & de Gelder (1997) have suggested, metrical information plays a crucial role in lexical segmentation during lexical activation and this seems to be borne out by the data in the present study. In our CVC ~ CVCV word pairs (Experiment 1a), the addition of a vocalic segment also resulted in an additional syllable (i.e. $[\text{kɑl}]_\sigma \sim [\text{kɑ}]_\sigma[\text{li}]_\sigma$, not $*[\text{kɑl}]_\sigma[\text{i}]_\sigma$) and therefore a change in syllable type (open to closed) and misalignment of boundaries between the prime and target. In the CVCV ~ CVCVC type (Experiment 1b), the number of syllables remained constant, but a change in the **type** of syllable (open to closed) was introduced in the second syllable: $[\text{bɑ}]_\sigma[\text{t̪i}]_\sigma \sim [\text{bɑ}]_\sigma[\text{t̪ik}]_\sigma$, not $*[\text{bɑt̪}]_\sigma[\text{ik}]_\sigma$. Both of these syllabic changes conceivably enhance the effect of mismatch between the word pairs, further facilitating exclusion of cohort competitors. In Experiment 1c (the $CVCV_1 \sim CVCV_2$ type), the syllabic structure of both prime and target was the same: $[\text{po}]_\sigma[\text{ri}]_\sigma \sim [\text{po}]_\sigma[\text{rɑ}]_\sigma$. Thus, there was no syllable mismatch, feasibly making it harder to reduce the number of lexical competitors for these word pairs.

3 Experiments 2a–2c: Morphological priming

The aim of this second set of experiments was to compare the effect of morphologically-related pairs to those of purely phonologically-related pairs. As seen in Experiments 1a–1c, with pure form overlap, we found significantly less priming. For the morphologically-related pairs, however, we do predict to observe priming effects. Below we present the findings from three types of morphologically-related word pairs that involved either the addition/deletion of one vowel (Experiment 2a: CVC ~ CVCV), the addition/deletion of one consonant (Experiment 2b: CVCV ~ CVCVC), or a change of a final vowel (Experiment 2c: $CVCV_1 \sim CVCV_2$). For the types where the prime and target differ in word length (i.e. Experiments 2a and 2b), we also investigated the effect of directionality; that is, whether there was an effect of using short words as primes for longer words (e.g. দাগ ~ দাগী*,* [d̪ɑg] ~ [d̪ɑg-i], 'mark, stain' ~ 'mark-ADJ, stained') as well as longer words as primes for shorter ones (দাগী ~ দাগ, [d̪ɑg-i] ~ [d̪ɑg], 'mark-ADJ, stained' ~ 'mark, stain').

3.1 Method

3.1.1 Participants

Participants were the same as those in Experiments 1a–1c. All participants completed the form-priming experiments first, followed by the morphological-priming experiments.

3.1.2 Materials

32 morphologically-related word pairs matching the segmental structure of the form-related stimuli were selected (Table 8; stimuli for Experiments 2a–2c are listed in Appendix B). For each word pair, each word was used as a prime as well as a target in different lists. As languages very rarely allow for completely matched sets of stimuli in all aspects, there are some differences between the stimulus types in the three experiments regarding their morphological relationship and word class.

Stimuli for the CVC. ↔ CV.CV type (Experiment 2a) consisted of derivationally-related noun ~ adjective pairs. The stimulus sets for the remaining two groups, CV.CV ↔ CV.CVC (Experiment 2b: 1.PRES ~ 2INT.PRES) and $CV.CV_1$ ↔ $CV.CV_2$ (Experiment 2c: 3.PRES ~ 2FAM.PRES), inflectional targets were used due to the fact that these structural relationships cannot be found in sufficient quantity in derivationally-related items in Bengali. As in Experiments 1a–1c, 16 control words and 32 pseudo-word pairs with matching syllable structure were chosen for each type and half of the pseudo-word pairs were related in a similar way to the real word pairs, the rest unrelated.

Condition	CVC ↔ CVCV	CVCV ↔ CVCVC	$CVCV_1$ ↔ $CVCV_2$
Critical word pair (gloss)	d̪eb ↔ d̪eb-i *deity.M ↔ deity-F*	d̪ekʰ-i ↔ d̪ekʰ-iʃ *see-1.PRES ↔ see-2INT.PRES*	kʰol-e ↔ kʰol-o *open-3.PRES ↔ open-2FAM.PRES*
Pseudo-word (gloss)	t̪il → *t̪ilo *sesame → –*	ʤit̪-i → *ʤit̪ɑʃ *win-1.PRES → –*	ʧɑp-i → *ʧɑpu *press-1.PRES → –*

Table 8. Sample word pairs used in Experiments 2a–2c.

3.1.3 Design and procedure

The design and procedure were the same as those in Experiments 1a–1c. The only difference is that, instead of purely phonologically-related critical word pairs, morphologically-related word pairs were used. Hence, four versions of the morphological priming sequence were created and distributed across four lists with the same pseudo-randomization procedure as explained in 2.1.4 to ensure minimization of strategic processing effects.

3.2 Results

Data were cleaned and analyzed in a similar manner as reported in 2.1.6. Items and participants with less than 60% accuracy were excluded: this resulted in a loss of 13.6% of the data (1678 data points). To enhance the normality of the RT distribution, RTs of less than 200ms and those above/below two standard deviations of each participant were excluded. This resulted in a further loss of 4.2% of data (445 data points). We next report on the findings for each type.

3.2.1 Experiment 2a: CVC ~ CVC-V

Experiment 2a tested the relationship between morphologically-related word pairs that differed in the presence/absence of a final vowel (e.g. দেব ~ দেবী, [deb] ~ [deb-i], 'deity.M' ~ 'deity-F'). The optimal model[18] contained an interaction between the two main effects *Relatedness* and *Direction* and random intercepts for subjects and targets. This interaction was significant (Est. = -5.70, SE = 2.39, t = -2.38), and removing the interaction from the analysis affected goodness of fit ($\chi^2(1) = 5.67$, p = .02*). This interaction was investigated in a post-hoc analysis through the *lsmeans* package (Tukey adjustment), in which both conditions were found to prime; however, SHORT → LONG configurations exhibited a stronger priming effect (Est. = 42.30, SE = 6.96, t = 6.07) than LONG → SHORT configurations (Est. = -27.33, SE = 10.27, t = 2.97) (Table 9).

The model showed a significant effect of prime on RTs (Table 9); that is, RTs to the related

[18] ReacTime~Relatedness*Direction+ (1|Date.Time.SJ) + (1|Target)

condition (e.g. দেব ~ দেবী, [d̪eb] ~ [d̪eb-i], 'deity.M' ~ 'deity-F') were faster than those for the unrelated/control condition (e.g. দেব ~ বেণী, [d̪eb] ~ [beni], 'deity.M' ~ 'braid'). Furthermore, there was an interaction between *Relatedness* and *Direction*: the SHORT → LONG direction (e.g. দেব ~ দেবী, [d̪eb] ~ [d̪eb-i], 'deity.M' ~ 'deity-F') primed more than the LONG → SHORT direction (e.g. দেবী ~ দেব, [d̪eb-i] ~ [d̪eb], 'deity-F' ~ 'deity.M').

Direction	Related		Control		Effect (in ms.)
	RT	SE	RT	SE	
SHORT → LONG (CVC ~ CVC-V)	560	10.4	602	10.5	42**
LONG → SHORT (CVC-V ~ CVC)	555	10.2	576	10.2	21*

Table 9. Mean reaction times (in ms) for Experiment 2a (N = 1509).

3.2.2 Experiment 2b: CVC-V ~ CVC-VC

Experiment 2b tested the relationship between inflectionally-related word pairs that differed in the presence/absence of a final consonant (e.g. দেখি ~ দেখিস, [d̪ekʰ-i] ~ [d̪ekʰ-iʃ], 'see-1.PRES' ~ 'see-2INT.PRES'). The optimal model[19] contained an interaction between the two main effects *Relatedness* and *Direction*, random slopes and intercepts between *Relatedness* and *Direction* and subjects, and random intercepts for targets. This interaction was significant (Est. = 5.98, SE = 2.43, t = 2.407), and removing the interaction from the analysis affected goodness of fit ($\chi^2(1) = 5.78$, p = 0.02*).

This interaction was investigated in a post-hoc analysis through the *lsmeans* package (Tukey adjustment), in which both conditions were found to prime; however, as the interaction indicated, LONG → SHORT configurations exhibited stronger priming (Est. = 42.5, SE = 6.82, t = 6.27) than SHORT → LONG configurations (Est. = -18.6, SE = 7.48, t = 2.48) (Table 10).

The model showed a significant effect of prime on RTs; that is, RTs to the related condition (e.g. দেখি ~ দেখিস, [d̪ekʰ-i] ~ [d̪ekʰ-iʃ], 'see-1.PRES' ~ 'see-2INT.PRES') were faster than those for the unrelated/control condition (e.g. দেখি ~ খাটিস, ([d̪ekʰ-i] ~ [kʰɑʈ-iʃ], 'see-1.PRES' ~ 'work hard-2INT.PRES'). Furthermore, there was an interaction between *Relatedness* and *Direction*: RTs for the LONG → SHORT direction (e.g. দেখিস ~ দেখি, [d̪ekʰ-iʃ] ~ [d̪ekʰ-i], 'see-2INT.PRES' ~ 'see-1.PRES') primed more for the SHORT → LONG direction (দেখি ~ দেখিস, [d̪ekʰ-i] ~ [d̪ekʰ-iʃ], 'see-1.PRES ~ see-2INT.PRES').

Direction	Related		Control		Effect (in ms.)
	RT	SE	RT	SE	
SHORT → LONG (CVCV ~ CVCVC)	596	11.0	616	11.0	20*
LONG → SHORT (CVCVC ~ CVCV)	532	10.7	575	10.7	43**

Table 10. Mean reaction times (in ms) for Experiment 2b (N = 1459).

3.2.3 Experiment 2c: CVC-V_1 ~ CVC-V_2

Experiment 2c tested the relationship between morphologically-related word pairs that differed in the change of a final vowel (e.g. খোলে ~ খোলো, [kʰol-e] ~ [kʰol-o], 'open-3.PRES' ~ 'open-2FAM.PRES'). For this priming configuration, only one fixed effect was relevant: *Relatedness*. The optimal model[20] contained *Relatedness* as a significant (Est. = -24.24, SE = 5.73, t = -4.22) fixed effect, and random slopes and intercepts for subjects and targets. Reducing *Relatedness* from the model structure significantly affected goodness of fit ($\chi^2(5) = 17.68$, p < .0001*). This model ap-

[19] ReacTime ~ Relatedness*Direction+ (1+Relatedness*Direction|Date.Time.SJ) + (1|Target)
[20] ReacTime ~ Relatedness + (1 |Date.Time.SJ) + (1 |Target)

peared homoscedastic when inspected visually. In this analysis, we found a significant priming effect of *Relatedness*: RTs for word pairs in the morphologically-related condition (e.g. খোলে ~ খোলো, [k^{h}ol-e] ~ [k^{h}ol-o], 'open-3.PRES' ~ 'open-2FAM.PRES') were significantly faster those for the unrelated condition (খোলে ~ পুষিস, [k^{h}ol-e] ~ [puʃ-iʃ], 'open-3.PRES' ~ 'keep pets-2FAM.PRES').

	Related		**Control**		**Effect**
	RT	**SE**	**RT**	**SE**	**(in ms.)**
CVCV$_1$ ~ CVCV$_2$	589	11.6	609	11.6	20*

Table 11. Mean reaction times (in ms) for Experiment 2c (N = 1302).

3.3 Discussion

The motivation for conducting a series of experiments parallel to the three pure phonological priming experiments was to test whether introducing morphological, and thus semantic, relatedness would lead to the emergence of priming effects. As in Experiments 1a–1c, we examined both different degrees of overlap and directionality of priming, and found that all three types of morphologically-related word pairs showed strong facilitation, as demonstrated in the literature (cf. Marslen-Wilson et al. 1994).

In Experiment 2a (CVC ~ CVC-V, e.g. দেব ~ দেবী, [deb] ~ [deb-i], 'deity.M' ~ 'deity-F') both morphologically-related configurations primed, but the SHORT → LONG direction exhibited stronger priming than the LONG → SHORT direction. This is in line with expectations from the Cohort model (Marslen-Wilson 1987, Marslen-Wilson & Tyler 1980, Marslen-Wilson & Welsh 1978): hearing দেব [deb] 'deity.M' activates a set of matching candidates, including the target দেবী [deb-i] 'deity-F'.

Experiment 2b tested the relationship between morphologically-related CVC-V ~ CVC-VC items that differed by the presence/absence of a final consonant. Once again, both configurations primed in this experiment; however, the LONG → SHORT configuration primed more than the SHORT → LONG configuration. This is initially a perplexing finding, as priming patterns were expected to be similar to those in Experiment 2a. While this could be, in part, ascribed to the difference in vowel length in the first syllable of the words, there is also the fact that the stimuli for this experiment consisted of inflectional items (e.g. দেখি ~ দেখিস, [d̪ek^{h}-i] ~ [d̪ek^{h}-iʃ], 'see-1.PRES' ~ 'see-2INT.PRES'). Bengali has three levels of politeness forms in second person pronouns which is also reflected in the inflectional marking on verbs: intimate (2INT, addressing children, animals, siblings, childhood friends), familiar (2FAM, addressing familiar people), and honorific (2HON, addressing less familiar adults, elders, etc.). Suffixes of the form VC are rare. We opted for the inflectional 2INT.PRES suffix /-iʃ/ which is perfectly regular; out of context, however, the word would appear unanticipated and perhaps even startling due to the very informal contexts in which it would be expected. Thus, as a lone word, forms such as দেখিস [d̪ek^{h}-iʃ] 'see-2INT.PRES' would be unexpected, leading to the observed pattern with slower RTs.

Finally, the morphologically-related word pairs in Experiment 2c, which differed in a single final vocalic segment (CVC-V$_1$ ~ CVC-V$_2$, e.g. খোলে ~ খোলো, [k^{h}ol-e] ~ [k^{h}ol-o], 'open-3.PRES' ~ 'open-2FAM.PRES'), also exhibited strong priming. All three experiments above display strong facilitation effects overall which is in line with previous findings using morphologically-related stimuli in cross-modal designs. Thus, adding the additional morphological and semantic relations to the pure form overlap results in significantly stronger activation of the target when the prime is processed. This applies to all conditions and all directions of priming. The difference in the degree of priming observed in Experiments 2a and 2b most likely results from the difference in the type of morphological relationship exhibited by the word pairs (derivational vs. inflectional) as well as the distribution of those forms in the language.

4 General discussion

In normal language processing, we are continuously analyzing the form and structure of incoming speech signals to understand their meaning. At the same time, we unavoidably encounter situations in which words are contained within other words (e.g. *ham* in *hammer*). Such instances can overlap in form only without sharing meaning (e.g. *corn* ~ *corner*) or overlap in both form and meaning (e.g. *write* ~ *writer*). This study was concerned with the degree to which form overlap activates related items in the lexicon compared to overlap which is also morphological. We investigated three related central issues concerning the effect of phonological overlap on word recognition: the effect of modality on the processing of form overlap, the role of segmental and syllable structure, and the question whether the lexical status of the prime (i.e. fragment vs. full word) plays a role in activation of related targets. To this end, we designed two sets of cross-modal priming experiments in which the pattern of overlap between primes and targets was controlled and matched. Experiments 1a–1c investigated the effect of phonological form overlap on the degree of activation and facilitation, while Experiments 2a–2c contained items which were morphologically (and thus semantically) related.

The experiments were conducted using Bengali, a language which offered a suitably balanced set of stimuli. Importantly, the Bengali lexicon contains large numbers of purely phonologically- as well as morphologically-related word pairs with otherwise identical segmental structure. Moreover, Bengali morphology allows for both single vowel suffixes and single consonantal suffixes: e.g. নাক ~ নাকী, [nɑk] ~ [nɑk-i], 'nose' ~ 'nasal', মাখ ~ মাখে, [mɑkʰ] ~ [mɑkʰ-e], 'mix.2INT.IMP' ~ 'mix-3.PRES', ছোঁ ~ ছোঁন, [ʧʰõ] ~ [ʧʰõ-n], 'touch.2INT.IMP' ~ 'touch-2HON.PRES', and জমা ~ জমাট, [ʤɔmɑ] ~ [ʤɔmɑ-ʈ], 'collection' ~ 'collection-ADJ, collected'). Such existing word pairs offer an ideal opportunity to systematically investigate the effect of adding or deleting a single consonantal or vocalic segment, and thus a comparison can be made between word pairs which are either purely form-related and those which also have a morphological relationship.

In Experiments 1a–1c, we tested the effect of pure phonological overlap using strictly manipulated segmental structures that involved either the addition/deletion of one vocal (Experiment 1a: CVC ↔ CVCV), one consonant (Experiment 1b: CVCV ↔ CVCVC), or a change of a final vowel (Experiment 1c: $CVCV_1 \rightarrow CVCV_2$). We also investigated the effect of directionality; i.e. whether using shorter words as primes for longer words (e.g. কাল ~ কালি, [kɑl] ~ [kɑli], 'yesterday' ~ 'ink') resulted in different patterns of facilitation that the other direction (e.g. কালি ~ কাল, [kɑli] ~ [kɑl], 'ink' ~ 'yesterday'). We predicted, based on evidence for full-word priming in similar cross-modal conditions (cf. Marslen-Wilson et al. 1994), that phonologically-related items would not prime one another. This prediction was borne out in Experiments 1a and 1b, where no facilitation for cases involving an increase or decrease of one segment were found in either direction (e.g. কাল ~ কালি, [kɑl] ~ [kɑli], 'yesterday' ~ 'ink' and ডালি ~ ডালিম, [ɖɑli] ~ [ɖɑlim], 'basket' ~ 'pomegranate'; Table 12). Experiment 1c, however, which examined priming between form-related pairs differing by a single vocalic element ($CV.CV_1 \sim CV.CV_2$), elicited significant priming results.

Condition	**Experiment**	**Configuration**	**Priming?**	
			SHORT → LONG	**LONG → SHORT**
form-related	1a	CVC ~ CV.CV কাল ~ কালি [kɑl] ~ [kɑ.li] 'yesterday' ~ 'ink'	×	×
	1b	CV.CV ~ CV.CVC ডালি ~ ডালিম [ɖɑ.li] ~ [ɖɑ.lim] 'basket' ~ 'pomegranate'	×	×
	1c	$CV.CV_1 \sim CV.CV_2$ পরি ~ পোরা [po.ri] ~ [po.rɑ] 'fairy' ~ 'fill.VBN'	✓	

Table 12. Summary of findings for form-related word pairs.

As discussed in Section 1.1, studies examining the LONG → SHORT form priming configuration have elicited varied results: Jakimik et al. (1985) and Zhang & Samuel (2015) found priming for phonologically- and orthographically-related word pairs (e.g. *message* ~ *MESS*), while Marslen-Wilson et al. (1994) and Vroomen & de Gelder (1997) found none. Our results in Experiments 1a and 1b (CVC ~ CVCV and CVCV ~ CVCVC, respectively) mirror those from the latter studies and this applies to both priming directions.

These findings seem to be attributable, in part, to the cross-modal paradigm (auditory prime, visual target). Throughout the literature, cross-modal experiments (e.g. Marslen-Wilson et al. 1994, Vroomen & de Gelder 1997, Marslen-Wilson 1990) have regularly failed to elicit priming between form-related words, in either the SHORT → LONG or LONG → SHORT configurations. Two processes are involved when processing a visual target: on the one hand, input from the prime boosts the activation level of its phonologically-related target; on the other hand, the prime, which was just activated, competes strongly for selection (Grainger et al. 1991, Drews & Zwisterlood 1995). Therefore, the priming effect can be viewed as the net effect of the faciliatory cohort activation and the inhibitory lexical competition (as compared to the control condition). Auditory intramodal and auditory shadowing tasks (e.g. Jakimik et al. 1985, Radeau et al. 1989, Spinelli et al. 2001, Zhang & Samuel 2015) have generated significant priming effects for form-related words. Zhang & Samuel (2015) attribute their finding to the use of the auditory–auditory priming paradigm, which conceivably generates more sensitivity to words embedded in the beginning of other words (e.g. *PROPERty)*. Following this, an embedded target (e.g. *proper*) may be easier to recognize when its modality-specific representation is activated by the auditory signal, but less so when the target is in a different modality. Thus, the lack of priming in cross-modal paradigms can be explained if the degree of cohort activation is at par with the degree of lexical competition.

A secondary contribution to lexical competition relates to the lexical status of the primes in our experiments. Much of the evidence of facilitation in the SHORT → LONG priming configurations (e.g. *bull* ~ *BULLET*) comes from experiments employing segment priming; i.e. where primes were segments and not real words (e.g. [dɔ] in Marslen-Wilson 1990, and [ɑno] in Friedrich et al. 2013). In the present study, all primes are real words and, as discussed in Section 2.3.1, conceivably contribute a competition effect that is absent in segment priming experiments: that is, a real word (e.g. *dog*) will generate more competition than a word segment (e.g. [dɔ]). Therefore, any relationship that may exist between form-related words is inhibited not only by the cross-modal design but also by the semantic information activated by real-word primes.

However, despite the cross-modal design and the use of real word primes, pairs in Experiment 1c ($CVCV_1$ ~ $CVCV_2$, e.g. দাবি ~ দাবা, [d̪ɑbi] ~ [d̪ɑbɑ], 'claim' ~ 'chess') primed readily. This finding deviates from others employing this configuration (cf. Radeau et al. 1989, Slowiaczek & Hamburger 1992, Dufour & Peereman 2003, 2009), with the exception of McQueen & Sereno (2005). One likely explanation for the facilitation effect found in our data is that form priming is sensitive not only to segmental overlap but also syllable structure, as syllabification has been shown to play a significant role in word priming (cf. Emmorey 1989, Mehler et al. 1981, Dumay & Content 2012).

In Experiment 1a (CVC ~ CVCV), the addition of a vocalic segment resulted in syllable mismatch between prime and target: CVC ~ CV.CV, (e.g. কাল ~ কালি, [kɑl] ~ [kɑ.li], 'yesterday' ~ 'ink'. In Experiment 1b (CVCV ~ CVCVC), the number of syllables remained constant (CV.CV ~ CV.CVC) but a change in the type of syllable (open to closed) was introduced in the second syllable (e.g. ডালি ~ ডালিম, [ɖɑ.li] ~ [ɖɑ.lim], 'basket' ~ 'pomegranate'). The misalignment in syllable boundaries in these two experiments contributed to an additional difference between prime and target, further facilitating exclusion of any cohort competitors and thus reducing their level of activation. In Experiment 1c, there was no boundary misalignment between prime and target (e.g. পরি ~ পোরা, [po.ri] ~ [po.rɑ], 'fairy' ~ 'fill.VBN') which likely resulted in greater facilitation as competitors remained more strongly activated. In summary, our results show that relationships between form-related words are not straightforward. Modality, and thus the experimental paradigm used and syllable structure, as well as the lexical status of the prime all play a role in addition to the degree of segmental overlap and these effects deserve closer examination in order to ascertain the contribution of each individual factor.

In Experiments 2a–2c, where prime and target were not only related in form but also in morphological structure, strong facilitation was predicted in all conditions for items with identical segmental structures to those in Experiments 1a–1c. As expected, all three types of word pairs demonstrated strong priming effects, thus supporting findings from previous studies where morphologically-related (and semantically-transparent) items led to reliable facilitation of the target (Table 13). In other words, hearing the complex form activated the stem and vice versa.

Condition	Experiment	Configuration	Priming? SHORT → LONG	Priming? LONG → SHORT
morph-related	2a	CVC ~ CV.C-V দেব ~ দেবী [d̪eb] ~ [d̪e.b-i] 'deity.M' ~ 'deity-F'	✓*	✓
	2b	CV.C-V ~ CV.C-VC দেখি ~ দেখিস [d̪e.kʰ-i] ~ [d̪e.kʰ-iʃ] 'see-1.PRES' ~ 'see-2INT.PRES'	✓	✓*
	2c	CV.C-V1 ~ CV.C-V2 খোলে ~ খোলো [kʰo.l-e] ~ [kʰo.l-o] 'open-3.PRES' ~ 'open-2FAM.PRES'	✓	

Table 13. Summary of findings for morphologically-related word pairs (* denotes more priming for a configuration).

In Experiment 2a (CVC ~ CV.C-V), morphologically-related derived words and their root forms primed one another, and there was an interaction between word relatedness and priming direction: SHORT → LONG word pairs (e.g. দেব ~ দেবী, [d̪eb] ~ [d̪eb-i], 'deity.M' ~ 'deity-F') exhibited stronger priming than the LONG → SHORT word pairs (e.g. দেবী ~ দেব, [d̪eb-i] ~ [d̪eb], 'deity-F' ~ 'deity.M'). These findings are in line with expectations for lexical retrieval set out by major speech recognition models (e.g. Cohort), in which a shorter word will activate a longer related word, e.g. *dark* activates *darkness*, *darker*, *darkly*, and *darken.*

Experiment 2b (CV.C-V ~ CV.C-VC, দেখি ~ দেখিস, [d̪ekʰ-i] ~ [d̪ekʰ-iʃ], 'see-1.PRES' ~ 'see-2INT.PRES') elicited priming for inflectionally-related word pairs, with the priming effect stronger for the LONG → SHORT (e.g. দেখিস ~ দেখি, [d̪ekʰ-iʃ] ~ [d̪ekʰ-i], 'see-2INT.PRES' ~ 'see-1.PRES') pairs than the SHORT → LONG word pairs. This finding is contradictory to what we would expect for morphologically-related word pairs; however, it is likely that the unexpectedness of the 2INT forms is driving this effect.

Finally, Experiment 2c (CV.C-V1 ~ CV.C-V2, e.g. খোলে ~ খোলো, [kʰol-e] ~ [kʰol-o], 'open-3.PRES' ~ 'open-2FAM.PRES') also generated strong priming for inflectionally-related pairs that differed by the quality of the single vocalic segment.

We acknowledge that the prime and the target for the morphological pairs are phonologically, morphologically, and semantically related; hence the effect cannot be attributed to any one of these levels alone. What is important, though, is that using the exact same degree of phonological overlap, we observed a priming effect in all conditions which was absent in all but one of the pure phonological priming experiments.

The results of the form priming experiments (Experiments 1a–1c) underline the importance of considering differences in patterns of facilitation resulting from employing a particular experimental paradigm. While form-related items differing by the presence/absence of a single additional segment (Experiments 1a and 1b) failed to prime one another in the cross-modal (auditory–visual) paradigm, these findings are in opposition to those associated with intramodal lexical decision and shadowing tasks in which words related only in form largely generate more priming overall (cf. Jakimik et al. 1985, Dufour & Peereman 2003, Zhang & Samuel 2015). It seems that segmental overlap can result in priming **provided** there are no additional differences such as in terms of syllable structure (cf. Experiments 1a and 1b). In the form-priming experiments, the direction of priming, i.e. whether the longer or shorted item was used as the prime, did not result in any differences in the degree of facilitation (or lack of facilitation). Experiments 2a–2c showed that the addition of a morphological relationship did, indeed, result in strong facilitation between all prime–target pairs in both directions which corroborates earlier findings using cross-modal lexical decision tasks. The examination of the direction of priming, however, also contributes a further methodological caveat to our findings which relates to the precise morphological relationship of the stimuli (i.e. inflection vs. derivation) and, even more specifically, the distribution and connotations of these forms within the language.

This study has underlined how important it is to understand the interaction of morphology and phonology in priming tasks. We began by questioning whether words are represented in the mental lexicon with their phonological shape, and to what extent does the pure phonology activate a phonologically-related word once we add the morphological element to it. Previous priming studies have employed stimuli taken from languages in which stress alternations are crucial (e.g. English), and it is therefore almost impossible to compare phonological word-within-words without also changing other phonological properties. By using Bengali, we were able to more tightly control our stimuli; e.g., we could alternate word final vowels with no change in stress শোলা ~ ষোল [ˈʃolɑ] ~ [ˈʃolo] 'cork wood' ~ 'sixteen' and add a final full vowel and not just a schwa কল ~ কলা, [kɔl] ~ [kɔlɑ] 'tap' ~ 'banana'. Results indicated that there are a number of different factors which come to bear when related items are activated in the lexicon, and targeted investigations are necessary to establish the precise contributions of each factor during the process of lexical access and the activation of a phonological cohort of items.

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Appendix A: Form-related stimuli (Experiments 1a–1c)

Experiment 1a: CVC ~ CVCV

CVC words			CVCV words		
টাক	ʈak	bald spot	টাকা	ʈaka	rupee
কান	kan	ear	কানা	kana	blind
কাক	kak	crow	কাকী	kaki	father's younger brother's wife (aunt)
কাঁচ	kãʧ	glass	কাঁচা	kãʧa	raw
ঝোল	ʤʱol	gravy	ঝোলা	ʤʱola	bag
ধন	d̪ʱon	wealth	ধনে	d̪ʱone	coriander
কল	kɔl	tap	কলা	kɔla	banana
মাছ	maʧʰ	fish	মাছি	maʧʰi	fly
ফুল	pʰul	flower	ফুলো	pʰulo	swollen
ছিপ	ʧʰip	fishing rod	ছিপি	ʧʰipi	(bottle) cork
দান	d̪an	donation	দানা	d̪ana	seed
ভিড়	bʱiɽ[21]	crowd	ভীরু	bʱiru	coward
পুর	pur	stuffing (food)	পুরো	puro	full
তাল	t̪al	palm fruit	তালা	t̪ala	lock
পিঠ	piʈʰ	back (body)	পিঠে	piʈʰe	rice cake
মাল	mal	load.N	মালা	mala	garland
মোড়	moɽ	crossing	মোড়া	moɽa	cane seat
ছুঁচ	ʧʰũʧ	needle	ছুঁচো	ʧʰũʧo	musk-rat
গোল	gol	round	গলি	goli	small lane
চান	ʧan	bath	চানা	ʧana	chickpea
কাল	kal	yesterday, tomorrow	কালি	kali	ink
বাড়	baɽ	increase.N	বাড়ি	baɽi	house
প্যাঁচ	pæ̃ʧ	twist.N	প্যাঁচা	pæ̃ʧa	owl
ভোর	bʱor	dawn	ভোরী	bʱori	gold unit
ঝাল	ʤʱal	spicy hot	ঝালা	ʤʱala	solder.VBN
তাক	t̪ak	shelf	তাকা	t̪aka	see.VBN
ঘর	gʱɔr	room	ঘরা	gʱɔra	vat
পাত	pat̪	dinner place	পাতা	pat̪a	leaf
খাল	kʰal	ditch	খালি	kʰali	empty
হাত	hat̪	hand	হাতি	hat̪i	elephant
চাঁদ	ʧãd̪	moon	চাঁদা	ʧãd̪a	subscription
ভিত	bʱit̪	foundation	ভিতু	bʱit̪u	coward

[21] Although Kolkata Bengali distinguishes three rhotics orthographically (i.e. dental/alveolar র [r], retroflex ড় [ɽ], and an aspirated retroflex rhotic ঢ় [ɽʱ]), the two retroflex rhotics have long been neutralized into [ɽ]. Furthermore, in normal running speech, this generation does not really differentiate [r] and [ɽ]. Still, prejudice to maintain 'correct' Bengali pronunciation prevails and we have maintained the difference in IPA to match with the orthography. For the fourth author, there is no real difference.

Experiment 1b: CVCV ~ CVCVC

CVCV words			**CVCVC words**		
মশা	mɔʃɑ	mosquito	মশাল	mɔʃɑl	torch
পোষা	poʃɑ	pet, keep pets.VBN	পোশাক	poʃɑk	clothing
গোলা	golɑ	cannonball	গোলাপ	golɑp	rose
ডালি	ɖɑli	basket	ডালিম	ɖɑlim	pomegranate
গ্রহ	groho	planet	গ্রহণ	grohon	receiving
পাশা	pɑʃɑ	dice	পাষাণ	pɑʃɑn	stone, weight
বাটি	bɑʈi	bowl	বাটিক	bɑʈik	wax dye
পুরু	puru	thick	পুরুষ	puruʃ	male
মাসী	mɑʃi	mother's sister (aunt)	মাসিক	mɑʃik	monthly
মালি	mɑli	gardener	মালিক	mɑlik	boss
গড়া	gɔɽɑ	form.VBN	গরাদ	gɔrɑd̪	window grating
চালা	ʧɑlɑ	thatched roof	চালাক	ʧɑlɑk	shrewd
চুমু	ʧumu	kiss	চুমুক	ʧumuk	sip, draught
জবা	ʤɔbɑ	china rose	জবাব	ʤɔbɑb	reply
টিকি	ʈiki	little pigtail	টিকিট	ʈikiʈ	ticket
তালি	t̪ɑli	clap	তালিম	t̪ɑlim	instruction
তিমি	t̪imi	whale	তিমির	t̪imir	darkness
আশা	ɑʃɑ	hope	আষাঢ়	ɑʃɑɽ	(third month of Bengali calendar)
কাঠি	kɑʈʰi	small stick	কাঠিম	kɑʈʰim	bobbin, reel
কুলি	kuli	laborer	কুলীন	kulin	Brahmin
বাজা	bɑʤɑ	play.VBN (a sound)	বাজার	bɑʤɑr	market
মাতা	mɑt̪ɑ	mother	মাতাল	mɑt̪ɑl	drunk
নাগা	nɑgɑ	Naga (ethn.)	নাগাল	nɑgɑl	proximity
ডাকা	ɖɑkɑ	call.VBN	ডাকাত	ɖɑkɑt̪	robber
বরা	bɔrɑ	boar	বরাত	bɔrɑt̪	fate
বন্ধ	bɔnd̪ʱo	closed	বন্ধক	bɔnd̪ʱok	mortgage, pawning
বড়	bɔɽo	large	বরণ	bɔron	formal welcoming
বালি	bɑli	sand	বালিশ	bɑliʃ	pillow
মধু	mod̪ʱu	honey	মধুর	mod̪ʱur	pleasant voice
তরু	t̪oru	plant, tree	তরুণ	t̪orun	young man
মানী	mɑni	proud	মানিক	mɑnik	ruby
হাজা	hɑʤɑ	chilblain	হাজার	hɑʤɑr	thousand

Experiment 1c: CVCV$_1$ ~ CVCV$_2$

CVCV$_1$ words			**CVCV$_2$ words**		
পরী	pori	fairy	পোরা	porɑ	fill.VBN
কচু	koʧu	taro root	কচি	koʧi	tender, young
মেজো	meʤo	second eldest	মেজে	meʤe	floor
বাটা	bɑʈɑ	paste, grind.VBN	বাটি	bɑʈi	bowl
ছোট	ʧʰoʈo	small	ছোটা	ʧʰoʈɑ	run.VBN
নাড়ু	nɑɽu	coconut sweet	নারী	nɑri	woman
মুড়ি	muɽi	puffed rice; hem	মুড়ো	muɽo	head (of a fish)
ছানি	ʧʰɑni	cataract	ছানা	ʧʰɑnɑ	curd
জালি	ʤɑli	trellis	জ্বালা	ʤɑlɑ	burning sensation
ঝাঁপা	ʤʱɑ̃pɑ	jump	ঝাঁপি	ʤʱɑ̃pi	small basket
গালি	gɑli	obscenity	গালা	gɑlɑ	lac, sealing wax
বিধি	bid̪ʱi	edict	বিধু	bid̪ʱu	moon
শাড়ী	ʃɑɽi	sari	সাড়া	ʃɑɽɑ	response
গুলি	guli	bullet	গুলো	gulo	(collective suffix)
ছাতা	ʧʰɑt̪ɑ	umbrella	ছাতু	ʧʰɑt̪u	barley meal
জানু	ʤɑnu	knee	জানা	ʤɑnɑ	know.VBN
ঘড়ি	gʱoɽi	clock	ঘোড়া	gʱoɽɑ	horse
তুলো	t̪ulo	cotton wool	তুলি	t̪uli	brush
শোলা	ʃolɑ	cork wood	ষোল	ʃolo	sixteen
আলো	ɑlo	light	আলু	ɑlu	potato
কোটি	koʈi	crore	কটু	koʈu	acrid, bitter
পালা	pɑlɑ	(one's) turn	পালী	pɑli	margin
গুঁড়ি	gũɽi	tree stump	গুঁড়ো	gũɽo	powder
পেটি	peʈi	belt, fish belly	পেটা	peʈɑ	beaten
আঁটি	ɑ̃ʈi	bundle	আঁটা	ɑ̃ʈɑ	tightly closed
ফুটি	pʰuʈi	muskmelon	ফুটা	pʰuʈɑ	hole, crack
বাসা	bɑʃɑ	home, house	বাসী	bɑʃi	stale
মাঝি	mɑʤʱi	boatman	মাঝে	mɑʤʱe	sometimes, in the middle
দাবি	d̪ɑbi	claim	দাবা	d̪ɑbɑ	chess
আড়া	ɑɽɑ	crooked	আড়ি	ɑɽi	quarrel
কালো	kɑlo	black	কালি	kɑli	ink
ভারি	bʱɑri	heavy	ভারা	bʱɑrɑ	scaffolding

Appendix B: Morphologically-related stimuli (Experiments 2a–2c)

Experiment 2a: CVC ~ CVC-V

CVC words			CVC-V words		
জ্ঞান	gæn	knowledge	জ্ঞানী	gæn-i	wise person
সুখ	ʃukʰ	happiness, joy	সুখী	ʃukʰ-i	happy, joyful
দেব	d̪eb	deity.M	দেবী	d̪eb-i	deity-F
ঢাল	ɖʱal	shield	ঢালী	ɖʱal-i	shield bearer
রাজ	raʤ	kingdom	রাজা	raʤ-a	king
দাঁড়	d̪ãɽ	oar	দাঁড়ী	d̪ãɽ-i	oarsman
দাস	d̪aʃ	servant	দাসী	d̪aʃ-i	maid
ঢাক	ɖʱak	drum	ঢাকী	ɖʱak-i	drummer
ভুল	bʱul	wrong	ভুলো	bʱul-o	mistake
জল	ʤɔl	water	জলা	ʤɔl-a	swamp
তাঁত	t̪ãt̪	loom	তাঁতী	t̪ãt̪-i	weaver
গুণ	gun	quality, talent	গুণী	gun-i	talented
তেল	t̪el	oil	তেলা	t̪el-a	oily
কাঠ	kaʈʰ	wood	কাঠি	kaʈʰ-i	small stick
ফাঁক	pʰãk	gap	ফাঁকা	pʰãk-a	empty
দূর	d̪ur	far	দূরে	d̪ur-e	far-LOC
ব্যাঁক	bæ̃k	bend	ব্যাঁকা	bæ̃k-a	bent
নাক	nak	nose	নাকী	nak-i	nasal
দাগ	d̪ag	mark, stain	দাগী	d̪ag-i	mark-ADJ, stained
চাষ	ʧaʃ	plow	চাষী	ʧaʃ-i	farmer
নাচ	naʧ	dance.N	নাচা	naʧ-a	dance-VBN
প্রাণ	pran	life	প্রাণী	pran-i	living being
রাগ	rag	anger	রাগী	rag-i	angry
সাজ	ʃaʤ	dress, outfit	সাজা	ʃaʤ-a	dress-VBN
পাপ	pap	sin	পাপী	pap-i	sinner
খুন	kʰun	murder	খুনী	kʰun-i	murderer
বেশ	beʃ	enough	বেশী	beʃ-i	more
দেশ	d̪eʃ	country	দেশী	d̪eʃ-i	domestic
জাত	ʤat̪	born, caste	জাতী	ʤat̪-i	people, nation
নীচ	niʧ	low	নীচু	niʧ-u	bow (down)
জট	ʤɔʈ	tangle	জটা	ʤɔʈ-a	matted hair

Experiment 2b: CVC-V ~ CVC-VC

CVC-V words			**CVC-VC words**		
নাচি	nɑʧ-i	dance-1.PRES	নাচিস	nɑʧ-iʃ	dance-2INT.PRES
দেখি	d̪ekʰ-i	see-1.PRES	দেখিস	d̪ekʰ-iʃ	see-2INT.PRES
চলি	ʧol-i	walk-1.PRES, wander-1.PRES	চলিস	ʧol-iʃ	walk-2INT.PRES, wander-2INT.PRES
শিখি	ʃikʰ-i	learn-1.PRES	শিখিস	ʃikʰ-iʃ	learn-2INT.PRES
ঢুকি	ɖʱuk-i	enter-1.PRES	ঢুকিস	ɖʱuk-iʃ	enter-2INT.PRES
হাঁটি	hɑ̃ʈ-i	walk-1.PRES	হাঁটিস	hɑ̃ʈ-iʃ	walk-2INT.PRES
ফেলি	pʰel-i	throw-1.PRES	ফেলিস	pʰel-iʃ	throw-2INT.PRES
চিনি	ʧin-i	recognize-1.PRES	চিনিস	ʧin-iʃ	recognize-2INT.PRES
লিখি	likʰ-i	write-1.PRES	লিখিস	likʰ-iʃ	write-2INT.PRES
শুঁকি	ʃũk-i	smell-1.PRES	শুঁকিস	ʃũk-iʃ	smell-2INT.PRES
মারি	mɑr-i	hit-1.PRES	মারিস	mɑr-iʃ	hit-2INT.PRES
করি	kor-i	do-1.PRES	করিস	kor-iʃ	do-2INT.PRES
পড়ি	poɽ-i	read-1.PRES	পড়িস	poɽ-iʃ	read-2INT.PRES
মুছি	muʧʰ-i	wipe-1.PRES	মুছিস	muʧʰ-iʃ	wipe-2INT.PRES
খুঁজি	kʰũʤ-i	search-1.PRES	খুঁজিস	kʰũʤ-iʃ	search-2INT.PRES
পারি	pɑr-i	be able-1.PRES	পারিস	pɑr-iʃ	be able-2INT.PRES
বেলি	bel-i	roll pastry-1.PRES	বেলিস	bel-iʃ	roll pastry-2INT.PRES
বলি	bol-i	say-1.PRES	বলিস	bol-iʃ	say-2INT.PRES
ছিঁড়ি	ʧʰĩɽ-i	tear-1.PRES	ছিঁড়িস	ʧʰĩɽ-iʃ	tear-2INT.PRES
ঝুলি	ʤʱul-i	swing-1.PRES	ঝুলিস	ʤʱul-iʃ	swing-2INT.PRES
বাঁধি	bɑ̃d̪ʱ-i	tie up-1.PRES	বাঁধিস	bɑ̃d̪ʱ-iʃ	tie up-2INT.PRES
হাসি	hɑʃ-i	laugh-1.PRES	হাসিস	hɑʃ-iʃ	laugh-2INT.PRES
ঠেলি	ʈʰel-i	push-1.PRES	ঠেলিস	ʈʰel-iʃ	push-2INT.PRES
মিশি	miʃ-i	mix-1.PRES	মিশিস	miʃ-iʃ	mix-2INT.PRES
ঘুরি	gʱur-i	turn around-1.PRES	ঘুরিস	gʱur-iʃ	turn around-2INT.PRES
জানি	ʤɑn-i	know-1.PRES	জানিস	ʤɑn-iʃ	know-2INT.PRES
বেচি	beʧ-i	sell-1.PRES	বেচিস	beʧ-iʃ	sell-2INT.PRES
বসি	boʃ-i	sit-1.PRES	বসিস	boʃ-iʃ	sit-2INT.PRES
ফিরি	pʰir-i	return-1.PRES	ফিরিস	pʰir-iʃ	return-2INT.PRES
খুলি	kʰul-i	open-1.PRES	খুলিস	kʰul-iʃ	open-2INT.PRES
জাগি	ʤɑg-i	wake up-1.PRES	জাগিস	ʤɑg-iʃ	wake up-2INT.PRES
ছাড়ি	ʧʰɑɽ-i	release-1.PRES	ছাড়িস	ʧʰɑɽ-iʃ	release-2INT.PRES

Experiment 2c: CVC-V_1 ~ CVC-V_2

CVC-V_1 words			**CVC-V_2 words**		
নাচে	nɑʧ-e	dance-3.PRES	নাচো	nɑʧ-o	dance-2FAM.PRES
কাঁদে	kɑ̃d̪-e	cry-3.PRES	কাঁদো	kɑ̃d̪-o	cry-2FAM.PRES
হাঁটে	hɑ̃ʈ-e	walk-3.PRES	হাঁটো	hɑ̃ʈ-o	walk-2FAM.PRES
খোলে	kʰol-e	open-3.PRES	খোলো	kʰol-o	open-2FAM.PRES
রাখে	rɑkʰ-e	keep-3.PRES	রাখো	rɑkʰ-o	keep-2FAM.PRES
ছেঁড়ে	ʧʰẽɽ-e	tear-3.PRES	ছেঁড়ো	ʧʰẽɽ-o	tear-2FAM.PRES
চেনে	ʧen-e	recognize-3.PRES	চেনো	ʧen-o	recognize-2FAM.PRES
ফেরে	pʰer-e	return-3.PRES	ফেরো	pʰer-o	return-2FAM.PRES
সেঁকে	ʃæ̃k-e	dry fry-3.PRES	সেঁকো	ʃæ̃k-o	dry fry-2FAM.PRES
শোবে	ʃo-b-e	sleep-FUT-3, lie down-FUT-3	শোবো	ʃo-b-o	sleep-FUT-1, lie down-FUT-1
গোঁজে	gõʤ-e	tuck in-3.PRES	গোঁজো	gõʤ-o	tuck in-2FAM.PRES
ধোবে	d̪ʱo-b-e	wash-FUT-3	ধোবো	d̪ʱo-b-o	wash-FUT-1
গোলে	gol-e	mix liquid-3.PRES	গোলো	gol-o	mix liquid-2FAM.PRES
তোলে	t̪ol-e	hold up-3.PRES	তোলো	t̪ol-o	hold up-2FAM.PRES
ঠেলে	ʈʰæl-e	push-3.PRES	ঠেলো	ʈʰæl-o	push-2FAM.PRES
খেলে	kʰæl-e	play-3.PRES	খেলো	kʰæl-o	play-2FAM.PRES
দেখে	d̪ækʰ-e	see-3.PRES	দেখো	d̪ækʰ-o	see-2FAM.PRES
ফেলে	pʰæl-e	throw-3.PRES	ফেলো	pʰæl-o	throw-2FAM.PRES
বেলে	bæl-e	roll pastry-3.PRES	বেলো	bæl-o	roll pastry-2FAM.PRES
ধরে	d̪ʱɔr-e	hold-3.PRES	ধরো	d̪ʱɔr-o	hold-2FAM.PRES
পড়ে	pɔɽ-e	read-3.PRES	পড়ো	pɔɽ-o	read-2FAM.PRES
চলে	ʧɔl-e	walk-3.PRES	চলো	ʧɔl-o	walk-2FAM.PRES
করে	kɔr-e	do-3.PRES	করো	kɔr-o	do-2FAM.PRES
বলে	bɔl-e	say-3.PRES	বলো	bɔl-o	say-2FAM.PRES
শেখে	ʃekʰ-e	learn-3.PRES	শেখো	ʃekʰ-o	learn-2FAM.PRES
লেখে	lekʰ-e	write-3.PRES	লেখো	lekʰ-o	write-2FAM.PRES
ভাবে	bʱɑb-e	think-3.PRES	ভাবো	bʱɑb-o	think-2FAM.PRES
ভরে	bʱɔr-e	fill-3.PRES	ভরো	bʱɔr-o	fill-2FAM.PRES
বসে	bɔʃ-e	sit-3.PRES	বসো	bɔʃ-o	sit-2FAM.PRES
ছোঁড়ে	ʧʰõɽ-e	throw-3.PRES	ছোঁড়ো	ʧʰõɽ-o	throw-2FAM.PRES
থাকে	t̪ʰɑk-e	stay-3.PRES	থাকো	t̪ʰɑk-o	stay-2FAM.PRES
মোছে	moʧʰ-e	wipe-3.PRES	মোছো	moʧʰ-o	wipe-2FAM.PRES