Cross-linguistic Phonological Transfer: The Influence of L1 Vowel Contrasts on L2 Tense-lax Vowel Acquisition

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Abstract

The perception and acquisition of non-native tense and lax vowel contrasts have been the subject of extensive research (Bustos et al., 2023; Chang, 2023; Fabra & Romero, 2012; Lai, 2010). Previous studies have highlighted various factors influencing the perception of these contrasts, such as linguistic background, exposure to the target language, and individual phonetic training (Casillas, 2015; Souza et al., 2017; Chang & Weng, 2012). However, there has been limited investigation into whether speakers can transfer discrimination abilities from the vowel contrasts in their first language (L1) to novel contrasts in a second language (L2) that differ in specific phonetic features. Focusing on this inquiry, the present research examines whether native speakers of Bangla, a language with tense/lax contrasts limited to mid vowels, can extrapolate this ability to discriminate tense/lax contrasts among high vowels in English, a language with tense/lax contrasts among both mid and high vowels. Through a forced-choice identification task involving English minimal pairs, data were collected from 43 adult Bangla speakers who had learned L2 English. Contrary to expectations, results indicated that these speakers were unable to effectively distinguish between tense and lax high vowels in English, suggesting that the presence of a similar contrast in L1 does not necessarily facilitate the acquisition of comparable distinctions in L2 across different vowel groups. Implications of the results for non-native vowel acquisition and the pedagogy of English language teaching to Bangla speakers are discussed.

Keywords: vowel acquisition, phonology, tense-lax vowel contrasts

Introduction

The ability to perceive and produce tense-lax vowel contrasts in a non-native language (L2) has been a matter of significant interest among linguists in recent years. Numerous studies (Bustos et al., 2023; Casillas, 2015; Chang, 2023; Chang & Weng, 2012; Fabra & Romero, 2012; Lai, 2010) have investigated the influence of the factors on the successful perception of these contrasts. Some of these factors include the size of the first language (L1) vowel inventory (Souza et al., 2017), the age at which L2 learning begins (Casillas, 2015; Chang & Weng, 2012), the extent of exposure to the relevant L2 contrasts, and the reliance on temporal versus spectral features for vowel discrimination (Gao et al., 2019). Additionally, the clarity of speech has been shown to impact learners' ability to differentiate between tense and lax vowels (Redmon et al., 2020).

The challenges L2 learners face when learning non-native vowel contrasts have been explained using many different models of L2 sound perception and production in the past few decades, particularly with the seminal works by Best (1993, 1995), Flege (1995, 2002), Kuhl (1991, 1992), Tyler et al. (2014), and so on. A prevailing assertion across these studies is the challenge language speakers face in perceiving or producing non-native speech sounds that lack acoustic similarity to any segment within their native language repertoire. For instance, Best's Perceptual Assimilation Model (PAM) (1993, 1995) suggests that non-native sounds closely resembling native linguistic sounds are likely to be assimilated and mapped onto existing native language categories. Conversely, non-native sounds with no clear native counterparts might be deemed "uncategorized," perceived as non-linguistic noises. Similarly, Flege's Speech Learning Model (SLM) (1995, 2002) argues that the acquisition of a non-native sound is particularly challenging when it does not resemble any existing native sound category.

Many theories and models of second language (L2) acquisition focus on how knowledge of individual sound categories from a first language (L1) transfers to and facilitates the acquisition of L2 sounds. However, a less explored dimension of this transfer is the extent to which specific phonological contrasts in L1, such as tense-lax vowel contrasts, aid in acquiring comparable contrasts in L2. The pertinent question is whether familiarity with tense-lax vowel contrasts in one's native language supports the learning of similar or different tense-lax contrasts in L2 vowels. Theoretically, understanding tense-lax contrasts among high vowels in L1 should promote the successful perception and acquisition of analogous tense-lax contrasts in L2 high vowels. This premise is expected to hold true for contrasts across other regions of the vowel space as well (cf. Casillas, 2015; Souza et al. 2017).

A more nuanced question concerns how speakers manage L2 tense-lax contrasts located in a different area of the vowel space compared to those in their L1. Specifically, does an L1 tense-lax contrast among mid vowels aid in perceiving tense-lax contrasts among high vowels in L2, or the reverse? Here, speakers possessing phonological knowledge of a tense-lax contrast are faced with the challenge of applying this knowledge to learn tense-lax contrasts in a new vowel space area in L2. If this phonological knowledge of the tense-lax contrast is transferable, one would expect speakers to exhibit high success in distinguishing tense-lax vowels in the targeted L2. Conversely, if this knowledge proves difficult to transfer, or if speakers typically favor phonetic knowledge transfer over phonological, a lower discrimination success rate may be observed. In other words, a high rate of success in discriminating novel L2 tense-lax contrasts in such contexts could signify that phonological knowledge of L1 tense-lax contrasts is a readily transferable linguistic construct, whereas low discrimination success may be interpreted as evidence of low transferability of such phonological constructs in L2 learning context.

With the above theoretical underpinnings under consideration, this study investigated the transferability of the phonological knowledge of L1 tense-lax vowel contrasts in novel L2 tense-lax contrasts. More specifically, we tested how transferable knowledge of L1 tense-lax contrast in mid vowels is transferable to an L2 tense-lax contrast in high vowels. As a test case, we obtained data from native speakers of Bangla, a language characterized by tense-lax contrasts among mid vowels (/e-ɛ/ and /o-ɔ/) but not high vowels. For the L2, we chose to use American English, which features tense-lax contrasts across both mid and high vowels (/i-ɪ/, /u-ʊ/, /e-ɛ/, and /o-ɔ/). Bangla speakers, therefore, possess phonological knowledge of tense-lax contrasts limited to mid vowels without analogous experience for high vowels within their L1. When confronted with American English's tense-lax distinctions among high vowels (/i-ɪ/ and /u-ʊ/), two outcomes emerge as possibilities. The first is that existing phonological knowledge of mid vowel contrasts may aid the perception of tense-lax distinctions in English high vowels. Alternatively, the specific phonological understanding of tense-lax contrasts in L1 may not extend to non-native vowel contrasts, leading to diminished performance by Bangla speakers in tasks requiring discrimination between English high tense and lax vowels.

Background

Tense-lax contrasts in Bangla

The vowel system in Bangla consists of seven vowels that are symmetrically distributed across categories of height: two high vowels, four mid-vowels, and one low vowel. Phonetically, these vowels are classified into four height categories: High, High-mid, Low-mid, and Low. A visual representation of this vowel distribution, based on the phonetic features described by Morshed (1972) and Thompson (2012), is provided in Figure 1. Additionally, certain vowels in the Bangla language have nasalized forms, which introduce phonological contrasts, a phenomenon documented by researchers including Islam (2018), Islam and Ahmed (2020), and Shamim (2011). Interestingly, while Bangla orthography distinguishes vowel symbols based on length, such as short-i versus long-i (which often happens to be associated with tense-lax contrasts as well), no such evidence of these length contrasts affect the spoken language has been reported (cf. Hai, 1985; Kostic & Das, 1972; Thompson, 2012).

	Front	Central	Back
High	i		u
High-mid	e		o
Low-mid	æ		ɔ

(a) Morshed 1972, p. 24

	front		mid			back	
high	i						u
high mid		e				o	
low mid			æ		ɔ		
low				a			

(b) Thompson 2012, p. 23

Figure 1: Bangla vowel inventory

It can be noted that /æ/ has been described as a "low-mid" vowel in the literature and not as a low vowel, as it is traditionally described in many phonetics and phonology literature in other languages. This description is actually consistent with the reported acoustic features of the vowels as well. Acoustic descriptions of Bangla vowels have shown that [æ] tends to behave F1 (first formant frequency) values similar to [ɔ] and a lower F1 value than the low vowel [a] (cf. Alam et al., 2008; Islam & Ahmed, 2020). Figure 2 provides a visual representation of the vowel positions in an acoustic space.

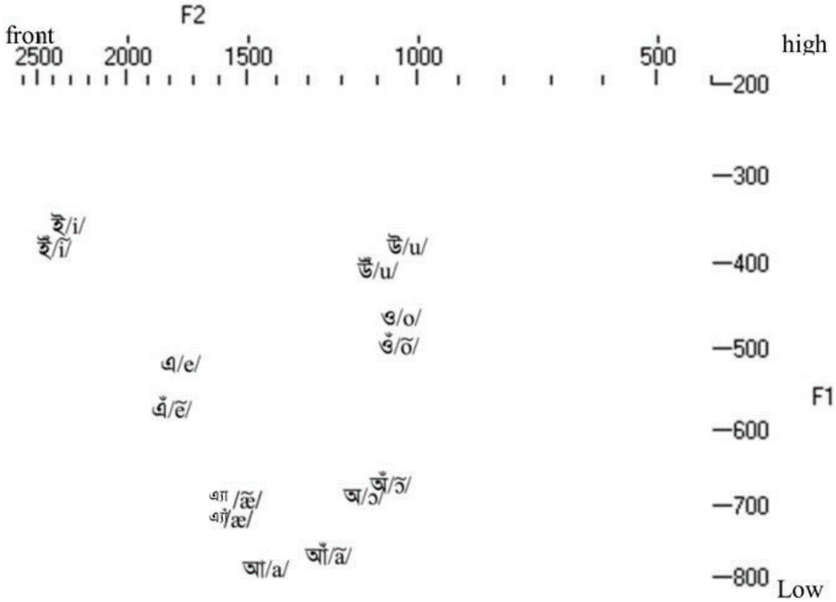

Figure 2: Bangla vowel acoustics (Alam et al., 2008, p. 9)

In the study of Bangla phonology, distinctions between the pairs of front and back mid vowels have been analyzed using [±ATR] feature (cf. Islam et al. 2023; Islam et al., 2023; Shamim 2011). This approach differentiates vowels based on their tongue root position, with the [+ATR] feature denoting tense vowels and the [-ATR] feature indicating lax vowels, following traditional phonological frameworks (Zsiga, 2013). Table 1 presents a feature chart for Bangla vowels, after Shamim (2011). It is to be noted that Shamim (2011) uses /ɛ/, instead of /æ/ to describe the low-mid front vowel in the inventory. This choice aligns with the phonetic descriptions of similar vowels in other languages, favoring /ɛ/ for its widespread usage in denoting a lax counterpart to the vowel /e/ (cf. Zsiga, 2013). Consequently, in Bangla, the mid vowels /e/ and /o/ are categorized as [+ATR] (tense), whereas /ɛ/ and /ɔ/ serve as their [-ATR] (lax) counterparts, ensuring a coherent classification consistent with conventional phonological practices. Note that the parenthesis around some signs have been added by the current authors to indicate those features are redundant to the concerned vowel. Besides distinguishing the mid vowels from each other, the tense-lax features have been described to actively participate in phonological processes, including metaphony, in Bangla (Shamim, 2011).

Table 1. Phonological features of Bangla vowels (Shamim, 2011: 8)

	i	e	ɛ	u	o	ɔ	a
high	+	-	-	+	-	-	-
low	-	-	-	-	-	-	+
ATR	(+)	+	-	(+)	+	-	(-)
round	-	-	-	+	+	+	-
back	-	-	-	+	+	+	+

Tense-lax contrasts in American English

The vowel inventory of American English is commonly identified to encompass 11 distinct vowels (excluding phonological diphthongs and schwa), as illustrated in Figure 3. Phonetically, these vowels are categorized based on height, backness, and rounding. However, from a phonological standpoint, they are delineated through five primary distinctive features. Table 2 outlines these features, offering a comprehensive representation of the vowels in terms of their phonological attributes. Notably, the Advanced Tongue Root (ATR), or tenseness feature, is not uniformly applicable across all 11 vowels. Specifically, only 8 vowels necessitate the ATR feature for accurate classification (instances marked by a minus sign within parentheses in the feature table indicate cases where this feature is deemed unnecessary or redundant). Therefore, the phonological contrasts significantly influenced by the [ATR] feature are /i-ɪ/, /u-ʊ/, /e-ɛ/, and /o-ɔ/. Among these, the high vowel contrasts of /i-ɪ/ and /u-ʊ/ are absent in the L1 vowel inventory of Bangla speakers, highlighting a gap in their native phonological system. Conversely, the mid-vowel contrasts of /e-ɛ/ and /o-ɔ/ bear a closer resemblance to the tense and lax distinctions present in Bangla, suggesting a parallel in the distribution of mid-vowel contrasts between the two languages.

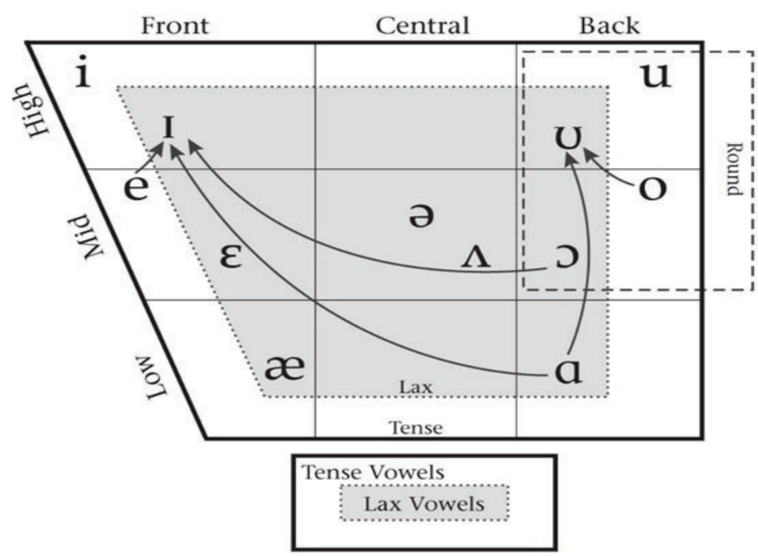

Figure 3: Vowels in General American English (Dawson et al., 2016, p. 57)

Table 2. Distinctive features of American English vowels (after, Zsiga, 2013 and Hayes, 2009)

	i	ɪ	e	ɛ	æ	u	ʊ	o	ɔ	ʌ	ɑ
high	+	+	-	-	-	+	+	-	-	-	-
low	-	-	-	-	+	-	-	-	-	-	+
ATR	+	-	+	-	(-)	+	-	+	-	(-)	(-)
round	-	-	-	-	-	+	+	+	+	-	-
back	-	-	-	-	-	+	+	+	+	+	+

The following summary table provides a comparison between the tense-lax contrasts available in Bangla and American English.

Table 3. Tense-lax contrasts available in Bangla and American English

Contrast	American English	Bangla
/i/ vs /ɪ/	yes	no
/e/ vs /ɛ/	yes	yes
/o/ vs /ɔ/	yes	yes
/u/ vs /ʊ/	yes	no

Perception of non-native tense/lax contrasts

Numerous studies have examined how non-native speakers perceive tense and lax vowel contrasts, focusing primarily on English as the target language, including its British, American, and Australian varieties. The range of first languages (L1) studied is relatively limited; most research has involved Mandarin speakers, followed by Spanish, with fewer studies including speakers of Italian, Polish, Danish, and Russian. This section evaluates the outcomes of these studies, specifically assessing whether participants can successfully discriminate between English tense and lax vowels and whether their native language includes a similar tense/lax contrast.

Numerous studies have documented the challenges Mandarin speakers face in distinguishing between English tense and lax vowel contrasts. This difficulty is potentially attributed to the fact that Mandarin does not include a tense/lax distinction in its vowel inventory. Gao et al. (2019) specifically explored how native Mandarin speakers perceived tense and lax vowels in German as their second language (L2). The results indicated that these learners struggled to differentiate these vowel contrasts. Similarly, Lai (2010) investigated Mandarin speakers' ability to discern English tense/lax sounds using a perception task, finding that participants were generally unsuccessful in distinguishing between English vowel pairs.

Redmon et al. (2020) analyzed the impact of clear speech on the ability of Mandarin speakers to integrate auditory and visual cues for English tense-lax distinctions. They found that clear speech improved the recognition of tense vowels (/i, ɑ, u/) across different modalities. However, lax vowels (/ɪ, ʌ, ʊ/) presented a disadvantage in visual-only settings, and this disadvantage was more pronounced in audio-visual presentations for Mandarin speakers, with no significant differences noted in purely auditory presentations. Chang and Weng (2012) also studied Mandarin speakers learning the tense/lax distinction in Canadian English, focusing on vowel production. Their findings also indicated difficulties in accurately producing these contrasts.

Not all studies report difficulties in distinguishing non-native tense/lax vowel distinctions. Zaorska (2015) investigated speakers of Polish, Italian, and Spanish—languages without a tense/lax contrast—on their ability to distinguish Australian English tense/lax distinctions. Participants, all residing in Australia, were tested on three contrasts: /o:/ vs. /ɔ/ (caught - cot), /i:/ vs. /ɪ/ (leave – live), and /ɐ:/ vs. /ɐ/ (Bart - but). The findings showed they were successful in distinguishing these contrasts, and participants employed different strategies based on their language backgrounds. The study also found that higher education levels enhanced the ability to discriminate these sounds, while the duration of residence in Australia did not have a significant impact.

Beyond Mandarin and Spanish, Kim (2012) studied Korean speakers, whose native language lacks tense/lax vowel distinctions. He investigated whether Korean learners could discriminate American English tense/lax vowel contrasts using the Categorical Discrimination Test. The findings revealed that Korean learners scored below 0.5 for both /i/-/ɪ/ and /u/-/ʊ/ distinctions, indicating a significant deficiency in their sensitivity to these contrasts. This suggests perceptual insensitivity to English tense/lax differences, as the learners struggled to recognize essential qualities in vowel formants.

Souza et al. (2017) conducted a broader study involving Danish, Portuguese, Catalan, and Russian speakers to determine whether the size of the L1 vowel inventory affects L2 vowel perception. Their results support the hypothesis that similarities between the L1 and L2 vowel inventories facilitate L2 learning. The study, which focused on American English, a language with distinct tense/lax features, found that among the participants, only those from Danish backgrounds showed native-like vowel perception in a forced-choice identification task. This success is attributed to the presence of tense/lax distinctions in Danish vowel space, a feature absent in the other three languages, leading to their participants' difficulties with tense/lax vowel distinctions.

As seen in the review above, the ability of non-native speakers to discern tense and lax vowel contrasts in a second language (L2) can be significantly influenced by the phonological features of their first language (L1). Studies reveal that when the L1 includes similar phonetic distinctions, as seen with Danish speakers, learners are better able to identify these contrasts in English, underscoring the advantage of having a phonologically aligned L1 inventory. Conversely, speakers of Mandarin and Korean, languages that lack tense/lax distinctions, encounter greater challenges in discriminating these contrasts in English. Interestingly, despite the absence of these distinctions in Spanish, Spanish speakers show a relatively higher success rate, suggesting that factors beyond direct phonological correspondence, such as broader phonological awareness or intensive language exposure, play a critical role in L2 phonetic learning. This highlights the complexity of language acquisition and suggests that successful discrimination of L2 sounds is not solely dependent on L1 inventory similarities but also on the extent of exposure to the target language and potentially other linguistic or cognitive factors. Therefore, understanding the specific phonological background of learners can help tailor language instruction to better meet their learning needs.

The synthesis of findings on the perception of tense and lax vowel contrasts among various first language (L1) backgrounds highlights the need to expand research to encompass a more diverse range of L1 contexts. Presently, the majority of studies concentrate on a limited selection of languages, which may not fully represent the vast diversity of global phonological systems. By incorporating data from a wider array of L1 backgrounds, researchers can gain a deeper understanding of how specific phonological features impact second language (L2) acquisition. To further explore this area, the current study focuses on Bangla speakers, whose language features tense-lax contrasts among mid vowels but not high vowels. This research aims to determine if having an L1 background that includes certain tense-lax contrasts aids in the acquisition of English tense and lax vowels among high vowels, thus contributing to broader insights into how L1 characteristics facilitate L2 vowel learning.

Method

The ability to perceive the differences between tense and lax vowels in American English by native speakers of Bangla was tested via a 2-alternative forced choice (2AFC) task. This section provides the details of the data collection method.

Participants

Perception data were gathered from 43 adult Bangla native speakers (the Bangladeshi dialect), comprising 15 women and 28 men. The participants were recruited through convenience sampling, utilizing social networks and personal contacts. All had learned English in academic settings and spoke it as a second language. None of the participants reported impaired hearing abilities. Participation was entirely voluntary, with no monetary compensation provided.

Stimuli

The experiment utilized 18 minimal pairs as stimuli, specifically focusing on the /i/ vs. /ɪ/ contrast through 12 pairs (e.g., "Beat" vs. "Bit") and the /u/ vs. /ʊ/ contrast with 6 pairs (e.g., "Pool" vs. "Pull"). All stimuli were monosyllabic cVc words, with the target vowel flanked by consonants, ensuring they were real English words. An adult female native speaker of American English from Minnesota, USA, recorded these words. The recordings were made as isolated words using a Zoom H4n Pro recorder, capturing the audio at a 44.1 kHz sampling rate and 16-bit quantization. The audio clips were then intensity-normalized utilizing Praat software (Boersma & Weenink, 2024).

Procedure

The experiment commenced with verbal instructions provided to the participants, who then gave their explicit consent to take part in the study. Following this, they received an online link to the experiment that was written and administered using PsyToolkit (Stoet, 2010; Stoet, 2017). The initial phase involved collecting basic demographic information, such as age, gender, and the region of Bangladesh where the participant was raised. Subsequently, participants were briefed on the experiment's expectations and procedures. They initiated the main experiment by pressing the space bar on their keyboard, beginning with a practice session of 10 trials to familiarize themselves with the task. Participants were restricted to completing the experiment only on a computer with a physical keyboard (with no option to run the experiment on tablets or phones).

During each trial, participants were presented with an auditory stimulus (a single word containing either a tense or lax vowel) while two written options were displayed on the computer screen. For instance, upon hearing "Beat," the screen would show the options "Beat" and "Bit" as two separate buttons on the screen, accompanied by the question "Which word did you hear?" Participants responded by pressing "A" for the option on the left or "L" for the right. Figure 4 illustrates a sample trial screen.

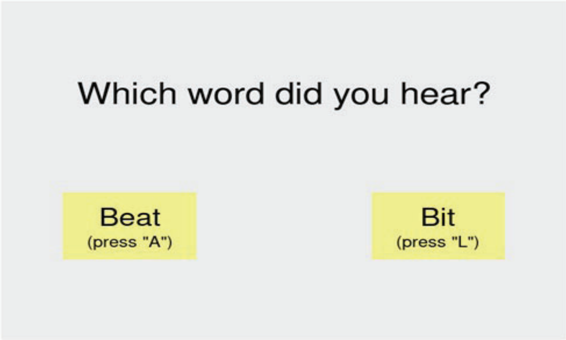

Figure 4: An example screen during a trial

Thus, in each trial, participants encountered an auditory stimulus consisting of a single word, alongside two visually presented words that constituted a minimal pair. To mitigate any biases stemming from the spatial arrangement of these options, the positioning of each word within the minimal pair was systematically alternated across trials. For instance, if in one trial the word "Beat" was heard and displayed on the left side of the screen (with "Bit" on the right), in a subsequent trial the arrangement would be switched, even if "Beat" was the auditory stimulus again. Participants had a 5000 millisecond (ms) window to respond to each trial, after which the experiment automatically advanced to the next trial.

Data processing

From the initial 43 participants, data from 7 were excluded due to their incomplete participation in the experiment. This led to the inclusion of responses from 36 participants (23 men and 13 women) in the analysis. For each of these participants, the ratio of correct responses to the total number of trials was calculated. This served as an indicator of their proficiency in accurately distinguishing between tense and lax vowel sounds. These ratios were then analyzed to uncover any significant trends.

Results

This section reports the results of the 2AFC perception experiment run in this study. We report the results of the high front and high back vowels separately as they are distinct pairs with tense and lax vowel pairs.

Front vowels

Figure 5 displays the distribution of correct response ratios for the 36 participants involved in the study. Responses are categorized on the X-axis as either pertaining to a tense or lax vowel within the auditory stimulus, with the Y-axis representing the proportion of accurate identifications. The notches around the median signify the 95% confidence interval for the median.

As indicated by Figure 5, the medians for both tense and lax vowel groups slightly exceeded the 50% mark (0.50 on the Y-axis). However, the spread between the first and third quartiles for both groups did not surpass the chance level, which is 0.50 in this case. Given that participants had a binary choice, a response rate aligning with chance would not significantly deviate from a ratio of 0.50 (or 50%). This suggests that, should participants be merely guessing, the central tendency of the distribution would consistently align near the 0.50 mark, implying an absence of significant underlying linguistic (perceptual) knowledge driving their responses. To statistically assess whether the mean values for either group (tense or lax) significantly differed from chance level performance, two separate one-sample independent samples t-tests (two-tailed) were conducted, setting the mean (*mu*) at 0.50.

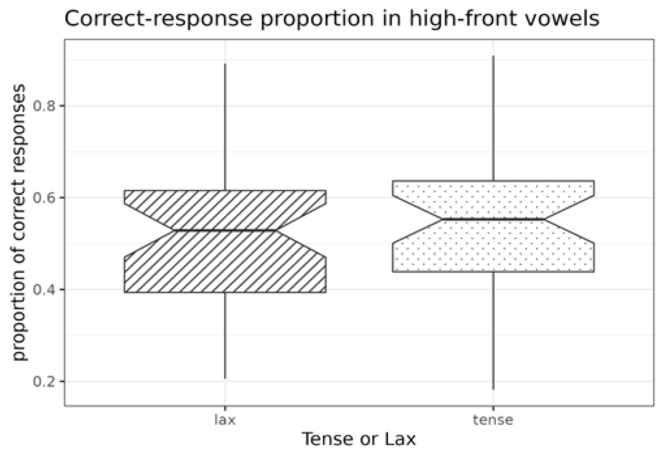

Figure 5: Distribution of correct-response ratio for all the participants (front vowels)

The One-sample t-tests showed that the mean values did not significantly deviate from 0.50, the level of chance. For the tense vowel group [Mean = 0.53, St. dev. = 0.17], the p-value was 0.217 (t(35) = 1.26), and for the lax vowel group [Mean = 0.52, St. dev. = 0.18], the p-value was 0.541 (t(35) = 0.62). These findings suggest that there is not sufficient evidence to assert that participants could discern the tense vowels from the lax vowels in the identification task. Consequently, it appears that participants were not consistently successful in distinguishing between tense and lax front vowels in English. These findings were consistent with both genders, as shown in Figure 6. We also investigated whether speakers tend to be better at identifying one of these two categories over the other. Since the data samples are paired per subject, we ran a two-samples paired t-test to examine whether the means of the tense and lax categories were significantly different. Results revealed no significant difference (t = 0.46, df = 35, p-value = 0.650) in the ratio of correct responses.

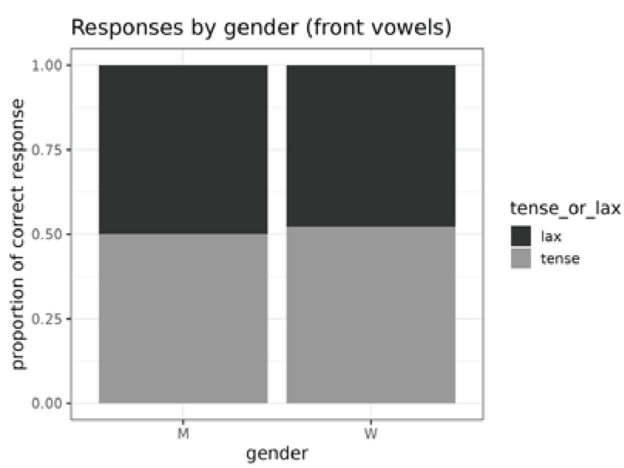

Figure 6: Ratio of correct responses for high vowels across men and women

Back vowels

The analysis of back vowels, employing the same methods as those used for the front vowels, produced analogous results; participants were not reliably able to distinguish between tense and lax vowels audibly. Figure 7 showcases the data distribution and summary. The figure reveals significant overlap in the interquartile ranges for both tense and lax vowel categories. The median and mean for the lax category closely approached the 0.50 chance level, with the confidence interval for the median encompassing this chance level. Conversely, the tense category's median notably differed from the chance level, as the 95% confidence interval for the median did not encompass 0.50, suggesting a potential distinction from the chance level. However, the mean for the tense category was nearer to the chance level than its median.

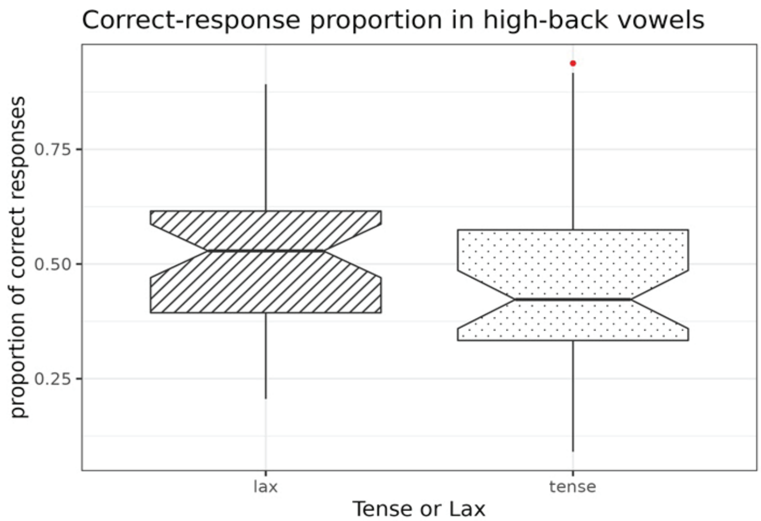

Figure 7: Distribution of correct-response ratio for all the participants (back vowels)

One-sample t-tests showed that the mean values did not significantly deviate from 0.50, the level of chance. For the tense vowel group [Mean = 0.45, St. dev. = 0.20], the p-value was 0.173 ($t(35) = -1.39$), and for the lax vowel group [Mean = 0.52, St. dev. = 0.18], the p-value was 0.541 ($t(35) = 0.62$). These findings, again, were consistent with both genders, as shown in Figure 8. As for front vowels, we also investigated whether speakers tend to be better at identifying one of these two categories. To test this, we ran a two-samples paired t-test to examine whether the means of the tense and lax categories were significantly different. Results revealed no significant difference ($t = -1.74$, df = 35, p-value = 0.091) in ratio of correct responses.

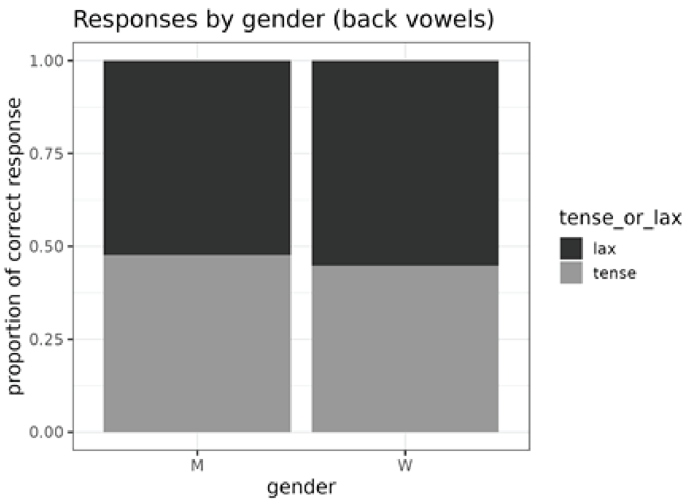

Figure 8: Ratio of correct responses for back vowels across men and women

Inter-speaker variation

In addition to the general patterns in the data, we also investigated variations among participants regarding their response accuracy for tense versus lax vowels, aiming to discern if participants generally exhibited better performance for one class of sounds over the other. Figures 9 and 10 display the accuracy scores of individual participants for both tense and lax vowels, concerning high and back vowel contrasts, respectively. In these figures, the X-axis lists the participants, while the Y-axis denotes their accuracy scores as ratio values, with tense and lax categories distinguished by black and grey colors, respectively. These visualizations reveal notable interspeaker differences in accuracy scores. A small subset of participants achieved significantly higher accuracy compared to others; however, the majority demonstrated scores hovering around or below the chance level, indicating near-chance or below-chance accuracy.

To quantitatively evaluate the differences in accuracy between tense and lax vowels, we conducted two-samples paired t-tests, separately for both front and back vowels. These analyses did not uncover any significant differences in accuracy scores for tense versus lax vowels, either for front vowels ($t = -0.46$, $df = 35$, $p = 0.650$) or for back vowels ($t = 1.74$, $df = 35$, $p = 0.090$), suggesting no prevalent bias or superior identification ability for either vowel class among the participants.

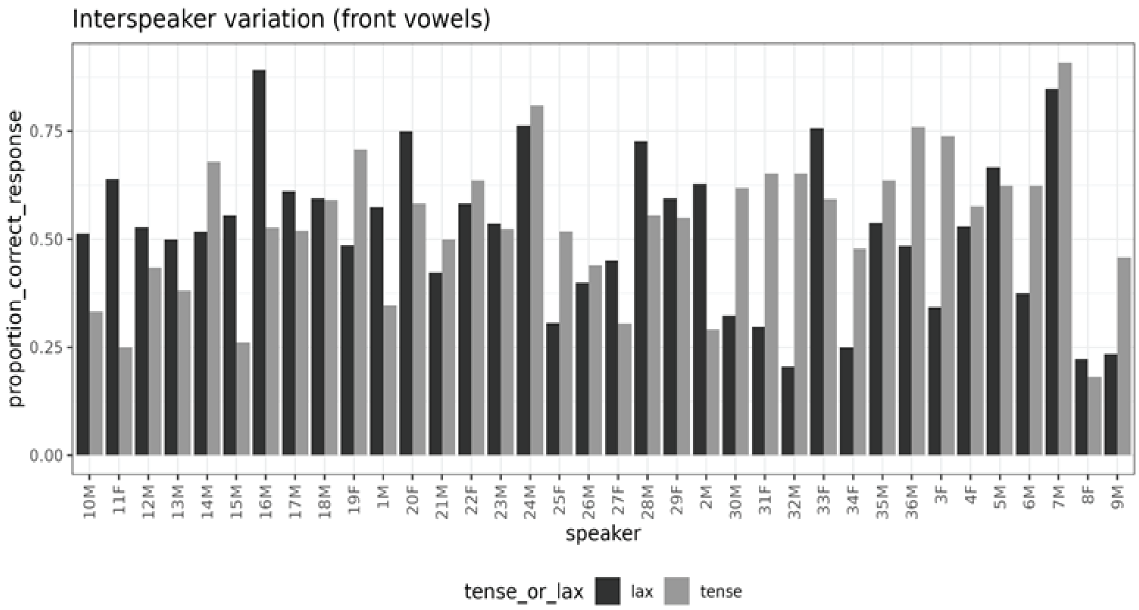

Figure 9: Interspeaker variation in accuracy scores in front vowels

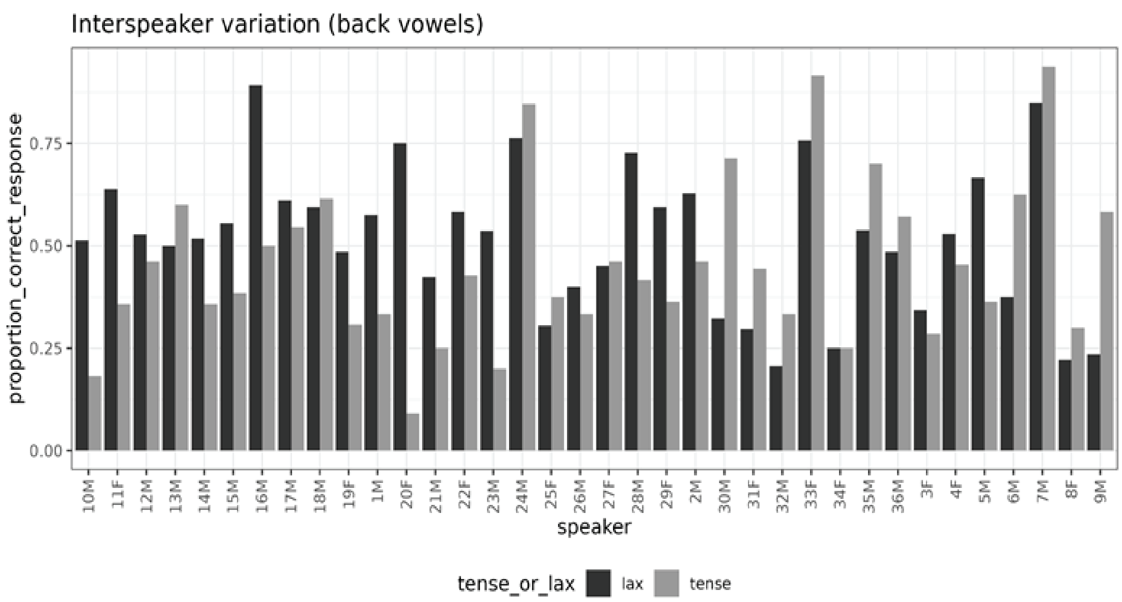

Figure 10: Interspeaker variation in accuracy scores in back vowels

Reaction times

In addition to measuring the accuracy of vowel identification, we also analyzed the reaction times (RT) associated with responses to stimuli featuring tense versus lax vowels. Figure 11 presents these findings, categorizing responses by accuracy (X-axis) and the time taken to reach a decision (Y-axis), with different patterns indicating the tense and lax categories. The data shows that participants responded faster when they correctly identified back lax vowels compared to back tense vowels. Conversely, the reaction times for incorrect answers showed the opposite pattern. This trend was not observed among front vowels. To statistically examine the differences in RT for correct identifications of tense and lax vowels (incorrect responses were not analyzed), we employed a linear mixed-effects model. This model included a fixed effect for the vowel category (tense or lax) and random intercepts for each participant. The analysis revealed a highly significant effect of the vowel category, with lax vowels eliciting significantly faster responses than tense vowels when correctly identified (β = 319.800, $t(456.34) = 4.96$, $p = .007$). The complete coefficients for the fixed effects can be found in Table 4.

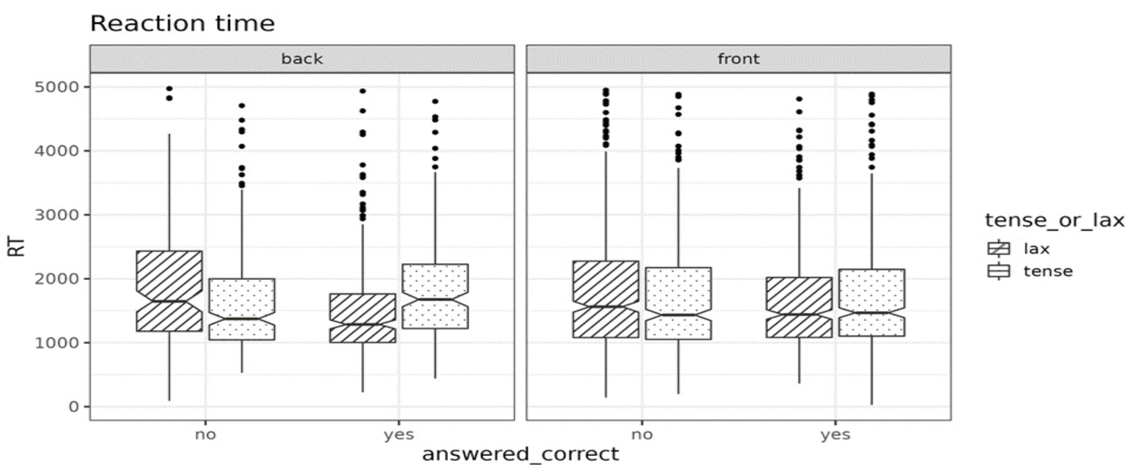

Figure 11: Reaction time for correct and incorrect responses

Table 4. Coefficients for fixed effects on Reaction Time

Fixed-effects:	Estimate	Std-Error	df	t-value	Pr(>|t|)
(Intercept)	1553.04	84.24	41.73	18.436	< .001
tense_or_lax-tense	319.80	64.49	456.34	4.96	.007

Discussion

This study highlights that Bangla speakers exhibit limited sensitivity to the tense and lax vowel distinctions present in English, despite Bangla itself having phonological contrasts among mid vowels based on this distinction. This observation underscores that possessing phonological knowledge of a tense-lax contrast in a first language (L1) does not automatically translate into an ability to recognize similar contrasts in a second language (L2). One possible explanation for this phenomenon is the variation in how tense and lax contrasts are phonetically implemented across languages. In English, tense vowels are not only more peripheral in their articulation but also longer in duration compared to their lax counterparts. In contrast, while Bangla tense vowels differ spectrally from their lax counterparts, they do not exhibit this duration difference (Islam et al., 2023).

Further complicating this scenario is the phonetic similarity between specific vowels across the two languages. For instance, the Bangla vowel /ɛ/ closely mirrors the English /æ/ vowel in terms of their first (F1) and second formants (F2), despite being phonologically categorized as lax. This similarity, as outlined in the research by Islam et al. (2023) and earlier findings by Alam et al. (2008), could hinder Bangla speakers' ability to accurately perceive and produce the English /ɛ/, attributing to the challenges in transferring tense-lax phonological knowledge from Bangla to English. These phonetic disparities offer a plausible explanation for the difficulties Bangla speakers face in adapting their L1 phonological knowledge to the nuances of tense-lax contrasts in an L2 context.

The analyses revealed no significant differences in accuracy scores between tense and lax vowels, regardless of whether they were front or back vowels in English. This outcome indicates that Bangla speakers did not display any advantage in distinguishing the tense-lax contrast for back vowels over front vowels in English. Given that the Bangla /ɛ/ is significantly different in vowel height (F1) compared to the English /ɛ/ (Alam et al., 2008; Islam et al., 2023), and the Bangla /o/-/ɔ/ distinction being spectrally similar to the English /o/-/ɔ/ distinction (Islam et al., 2023), it was expected that Bangla speakers would achieve higher accuracy in identifying tense and lax vowels among back vowels. However, this assumption was not supported by the data. Consequently, it appears that Bangla speakers do not have an advantage in discriminating tense-lax contrasts between front and back vowels.

The results of the reaction time analysis that the back lax vowel is recognized correctly faster than its tense counterpart can be an indication that the identification of back tense vowel involves more cognitive load to Bangla speakers, making the processing of tense vowels a more difficult task for them. Since Bangla inventory has a single vowel in the high back region while English has two (/u/ and /ʊ/), Bangla speakers are very likely to categorize both /u/ and /ʊ/ as a single vowel category, leading to a single category assimilation (see Perceptual Assimilation Model (PAM) (Best et al., 1993; 1995). However, the authors think that this single-category assimilation should be an instance of a category-goodness assimilation where the lax /ʊ/ is considered a better exemplar than /u/ (cf. Tyler et al., 2014). Therefore, when faced with the bad exemplar like the English /u/, bangla speakers should find it less straightforward than /ʊ/ in a categorization task, leading to a longer reaction time.

The observation that the back lax vowel is recognized more swiftly than its tense counterpart suggests that identifying back tense vowels poses a greater cognitive challenge for Bangla speakers. This increased difficulty is likely due to the richer vowel inventory in English compared to Bangla, particularly in the high back region where English distinguishes between /u/ and /ʊ/, whereas Bangla has only one corresponding vowel. Consequently, Bangla speakers might assimilate both English vowels into a single category, a phenomenon supported by the Perceptual Assimilation Model (PAM) proposed by Best and colleagues (1993; 1995). More specifically, we propose that this assimilation falls under what might be termed category-goodness assimilation, wherein the lax /ʊ/ is perceived as a more accurate representation of the Bangla equivalent than /u/ (in line with findings by Tyler et al., 2014). Thus, when Bangla speakers encounter the less familiar /u/ vowel, categorization becomes less straightforward, resulting in prolonged reaction times.

Conclusion

This study underscores the challenges that Bangla speakers face in distinguishing between tense and lax vowel distinctions in English, a difficulty that persists despite the presence of similar phonological contrasts in Bangla. The findings highlight a critical aspect of second language (L2) acquisition: having a phonological contrast in a first language (L1) does not guarantee the ability to recognize and use comparable distinctions in an L2. This limitation may be attributed to the different phonetic implementations of these contrasts across languages. For instance, while English tense vowels are characterized by more peripheral articulation and longer durations, Bangla tense vowels do not share these temporal characteristics, instead differing primarily in spectral properties. Such phonetic discrepancies complicate the transfer of phonological knowledge from L1 to L2.

One important factor to consider is the varying relationship between the phonology and phonetics of vowels across languages. Although both English and Bangla feature tense-lax contrasts among mid vowels, the actual phonetic realization of these vowels differs significantly between the two languages. Consequently, the way speakers perceive the connection between the abstract, phonological concept of tense-lax contrasts and their concrete phonetic implementation can vary markedly from one language to another. Therefore, even when a phonological contrast is transferred from a first language (L1) to a second language (L2), learners must still contend with the challenge of mastering its phonetic expression in the new language.

These observations suggest that effective L2 vowel training should consider these specific phonetic and perceptual challenges. Educators and curriculum developers need to focus on enhancing the perceptual sensitivity of L2 learners to these distinctions, perhaps by emphasizing the phonetic cues that are absent in the learners' L1. This approach could help mitigate the difficulties posed by L1-L2 phonetic and phonological discrepancies, thereby improving the acquisition of complex vowel systems in a new language.

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Appendix

Word lists used in the stimuli:

No.	Tense vowel	Lax vowel
1	bead	bid
2	beat	bit
3	deed	did
4	feat	fit
5	green	grin
6	keep	kip
7	leak	lick
8	mead	mid
9	neat	knit
10	peak	pick
11	teak	tick
12	seat	sit
13	shooed	should
14	suit	soot
15	wooed	wood
16	cooed	could
17	Luke	look
18	pool	pull