A probabilistic model of loanword accentuation in Japanese

Abstract

This paper presents a probabilistic model of loanword accentuation in Japanese, analyzing a corpus of 3,017 English-based loanwords. Through corpus analysis and computational modeling, the study reveals that Japanese loanword accentuation involves two distinct types of faithfulness effects, alongside markedness effects. First, there is a significant influence of the stress patterns of English source words and the epenthetic status of loanword syllables. This challenges the common assumption that accents driven by faithfulness are merely sporadic exceptions, highlighting instead a probabilistic interplay between faithfulness and markedness. Second, this study uncovers faithfulness to Japanese speakers' implicit knowledge of the English stress system. Rather than merely imitating the stress patterns of individual English words, Japanese speakers develop an internalized theory of the English stress system and mimic what they believe is the correct pronunciation according to their internalized theory.

1. Introduction

Loanword adaptation typically aims to maintain a high degree of perceptual similarity between the source form and its adapted loanword form, within the limits of the well-formedness principles of the borrowing language (e.g., Kang 2003, Kenstowicz & Suchato 2006, Yip 2006). In the context of suprasegmental adaptation (involving tone, stress, and pitch accent), the goal is to preserve the prominence of the source language while ensuring compliance with the suprasegmental restrictions of the borrowing language.

While the significant influence of perception in loanword adaptation is well-established (e.g., Boersma & Hamann 2009, Peperkamp, Vendelin, & Nakamura 2008, Silverman 1992), it remains an intriguing puzzle that faithfulness to the source language's prominence, especially in the adaptation of stress into pitch accent, is not consistently observed. Often, the source prominence is disregarded, even in the absence of obvious restrictions from the borrowing language (see Kang 2010 for a review). For example, in both North Kyungsang Korean (Kenstowicz & Sohn 2001) and South Kyungsang Korean (Lee 2009), the assignment of pitch accent to English loanwords is determined by the syllable structure of the loanwords, rather than their source prominence, even though accentuation in the native words is largely unpredictable.

Tokyo Japanese (henceforth "Japanese") presents an interesting case in this respect, with the degree of this faithfulness still being unclear. Although it is acknowledged that some loanwords preserve the source prominence (e.g., Ito & Mester 2016, Kubozono 2006, Shinohara 2000), such effects are generally considered negligeable and marginal to phonological grammar. This issue is elaborated upon in Section 2.2 below.

The primary goal of this study is to demonstrate that the uncertainty around the preservation of source prominence in Japanese loanword accentuation can be clarified using a data corpus and probabilistic modeling. Specifically, I employ Maximum Entropy Harmonic Grammar (Goldwater & Johnson 2003, Hayes & Wilson 2008) to statistically evaluate multiple factors that might influence this process, leading to the development of a more accurate and comprehensive model of loanword accentuation in Japanese. This approach enables the integration of subtle aspects of the data often missed in categorical models, which typically predict the most frequent outcome. Through these methods, this study reveals significant effects of two factors related to faithfulness, in addition to the effects of markedness.

First, this study confirms the significant influence of faithfulness to English source words: the stress patterns of the English source words and the epenthetic status of loanword syllables play a crucial role in determining loanword accentuation. This challenges the common assumption that accents driven by faithfulness are sporadic exceptions (see Section 2.2). Instead, the research highlights a probabilistic interaction between faithfulness and markedness, suggesting that faithfulness to the stress patterns of the English source words is a crucial factor in both the development and maintenance of a specific accent pattern, referred to as pre-antepenultimate-mora accent.

Second, this study uncovers faithfulness to Japanese speakers' implicit knowledge of the English stress system. Rather than merely imitating the stress patterns of individual English words, Japanese speakers develop an internalized theory of the English stress system and mimic what they believe is the correct pronunciation, particularly when faced with atypical source stress patterns. In the present case, since we are dealing with Japanese and English, I will refer this system as the Japanese Theory of English (JTOE). As we will see, a crucial form of evidence supporting the JTOE is the presence of hyperforeignisms (Janda, Joseph, & Jacobs 1994), i.e., loanwords whose accent patterns do not align with their source stress patterns or markedness principles but rather reflect the most common stress patterns in English. Examples include [íniɕaɾɯ] 'inítial' and [ɕíatoɾɯ] 'Seáttle'.

Overall, this study significantly enhances our understanding of loanword accentuation in Japanese by highlighting its multifaceted nature. It illustrates that deeper insights can be gained by employing probabilistic modeling in the study of loanword adaptation, in line with Zuraw, O'Flynn, and Ward (2019) on English loanwords in Tongan and Glewwe (2021) on English loanwords in Mandarin Chinese.

The paper is organized as follows. Section 2 provides background, summarizing pitch accent in Japanese and offering an overview of existing studies of Japanese loanword accentuation. Section 3 presents a descriptive analysis of the corpus data. In Section 4, I develop a series of probabilistic models of Japanese loanword accentuation, which support an approach incorporating both faithfulness to source words and the JTOE. Section 5 discusses the implications and remaining issues.

2. Background

2.1. Pitch accent in Japanese

Japanese words may be either accented, carrying a single pitch accent (henceforth "accent"), or unaccented.[1] The presence and location of accents in native and Sino-Japanese nouns have been traditionally considered unpredictable,[2] as exemplified by a well-known triplet: [háɕi] (initial accent) 'chopsticks', [haɕí] (final accent) 'bridge', and [haɕi] (unaccented) 'edge' (acute accent marks indicate accented moras). An exception to this is that the second mora of a heavy syllable – a moraic nasal (e.g., [ka<u>**ɴ**</u>kokɯ] 'Korea'), the first element of a geminate consonant ([ni<u>**p**</u>poɴ] 'Japan'), or the second element of a long vowel or a diphthong ([t͡ɕɯ<u>ː</u>gokɯ] 'China') – cannot carry an accent (Kubozono 1993, McCawley 1968).

This study adopts Ito and Mester's (2016) conventions for marking the accentuation of a word. That is, in addition to an acute accent mark, a superscript number is assigned to indicate the location of the accented mora counting backward from the end of the word (e.g., ^{3}[ínot͡ɕi] 'life', ^{2}[kokóɾo] 'heart', and ^{1}[atamá] 'head'). Unaccented words are assigned the number "0". Brackets […] and parentheses (…) indicate prosodic words and metrical feet, respectively. The symbols "L" and "H" denote light and heavy syllables, respectively (In Section 4.2., additional characters will be introduced to capture gradient syllable weight). Angle brackets <…> signify an epenthetic vowel[3].

2.2. Loanword accentuation in Japanese

The literature dates back to McCawley (1968), who discovered the "antepenultimate accent rule". The rule states that accented loanwords carry an accent on the syllable containing the antepenultimate mora (e.g., ^{3}[k<ɯ>ɾis<ɯ́>mas<ɯ>] 'Christmas', ^{4}[hambáːgaː] 'hamburger'). Later, Katayama (1998) and Kubozono (2006) noted that loanwords with certain syllable structures deviate from antepenultimate-mora accent. Specifically, they observed that loanwords ending in LH syllables tend to carry an accent on the syllable containing the pre-antepenultimate mora (e.g., ^{4}[dók<ɯ>taː] 'doctor', ^{5}[béːkaɾiː] 'bakery'). Kubozono attributed this accent pattern to a diachronic shift in the phonological grammar from the antepenultimate accent rule (i.e., ^{3}[LĹH], ^{4}[HĹH]) to a rule equivalent to the Latin Stress rule (Allen 1973): stress the penultimate syllable if it is heavy, otherwise stress the antepenultimate syllable (i.e., ^{4}[ĹLH], ^{5}[H́LH]). Furthermore,

[1] In Japanese, accent is phonetically manifested as a steep pitch fall, usually extending from the end of the accented mora to the next mora (Beckman & Pierrehumbert 1986). The phonetic realization of Japanese accent contrasts with English stress, which involves multiple cues, including greater excursion in fundamental frequency, longer duration, and stronger intensity (e.g., Beckman 1986, Laver 1994, Liberman 1960). When unaccented Japanese words are spoken in isolation, they carry phrasal prosody with initial and final Low boundary tones (%L and L%) and a phrasal High tone (i.e., H-) on the second mora (Beckman & Pierrehumbert 1986, Venditti 1997).

[2] A more recent view suggests that there are discernible statistical tendencies in the accent patterns of Native and Sino-Japanese words, serving as the foundation for accentuation in loanwords (Kubozono 2006, Kawahara 2015).

[3] In Japanese loanwords, the default epenthetic vowel is [ɯ]. The vowel [i] is inserted after palato-alveolar affricates [t͡ʃ, d͡ʒ] in source words, while the vowel [o] is inserted after alveolar stops [t, d] (Shoji & Shoji, 2014).

Kubozono (2006) found that four-mora loanwords ending in LL syllables tend to be unaccented (e.g., ^{0}[ameɾika] 'America', ^{0}[abokado] 'avocado'), unless the word-final syllable is epenthetic (e.g., ^{4}[mánmos<ɯ>] 'mammoth', ^{4}[ák<ɯ>ses<ɯ>] 'access'). In a more recent development, Ito and Mester (2016) put forth the most comprehensive and ambitious formal existing model that attempts to capture Japanese-internal markedness principles of loanword accentuation, which will be reviewed in Section 4.1 below.

As noted in Section 1, there is no consensus on the existence of faithfulness effects. Although it is widely recognized that Japanese speakers sometimes mimic the main prominence of source words (e.g., ^{5}[ák<ɯ>sent<o>] 'áccent', ^{1}[ɸondjɯ́] 'fondúe' (from French)) (e.g., Ito & Mester 2016, Kubozono 2006, Shinohara 2000), such faithfulness-driven accents have generally been considered exceptions to the phonological grammar and not been subject to serious investigation. For example, Ito and Mester (2016) acknowledge the occurrence of this phenomenon as an exception, stating that "Although the majority of loans do not take into account the prominence location of the source word, some newer loans preserve the original prominence location of the source words…" (p. 477). This perspective is underscored by the absence of faithfulness constraints in their Optimality Theoretic analyses, a characteristic shared with certain earlier analyses, notably those by Katayama (1998). Furthermore, in their effort to develop a taxonomy for loanword prosody, Davis, Tsujimura, and Tu (2012) describe English loanwords in Japanese as instances where the prosodic system of the source language has no influence.

One notable exception is Mutsukawa (2005, 2006), who argues that faithfulness to stress location of source words is the dominant factor in determining loanword accent of English loanwords.[4] However, this view might overestimate the impact of faithfulness effects. The basis for Mutsukawa's conclusion is the observation that the majority of English loanwords in his corpus preserved the English stress, but this group crucially includes words following the antepenultimate accent rule. Kubozono (2006) expresses an intermediate view, arguing that while the tendency of English loanwords to be accented (as opposed to unaccented)[5] comes from Japanese speakers' knowledge that English words are pronounced with a pitch fall in isolation, the location of the accent is determined by the native phonological grammar. Finally, Kubozono explores the influence of epenthetic syllables, observing that loanwords consisting of LH syllables tend to carry an accent on the final syllable when the initial syllable is epenthetic (e.g., ^{2}[p<ɯ>ɾéː] 'play', ^{2}[b<ɯ>ɾɯ́ː] 'blue').[6] Ito and Mester (2016) also mention a similar phenomenon, but such instances are treated as exceptions.

[4] Shinohara (2000) also argued that the primary stress of English words is generally preserved as accent in on-line adaptation (e.g., *pícnic* → [pík<ɯ>nikk<ɯ>]).

[5] Kubozono's survey shows that 71% of trimoraic native nouns and 51% of trimoraic Sino-Japanese nouns are unaccented, in contrast to just 7% of trimoraic loanwords.

[6] Shinohara (2000; 2004) observed the effects of epenthetic syllables in on-line adaptation of French words into Japanese (example). C. Ito (2014) noted this tendency in loanword accentuation in Yanbian Korean.

3. Descriptive analysis of the corpus data

In this section, I will present a descriptive analysis of corpus data, aiming to provide key empirical generalizations of Japanese loanword accentuation. These generalizations will form the basis for the modeling presented in Section 4.

3.1. Data

The data consists of English-based loanwords from the NHK Pronunciation and Accent Dictionary (2016). All loanwords in the dictionary were manually extracted, and their syllable structures and accent patterns were documented. Loanwords with multiple accent variants were counted separately[7], totaling 7378 loanwords. Sequences of two vowels ending in a high vowel (i.e., /ai/, /oi/, /ui/, /au/, /eu/, /iu/) were considered as diphthongs.[8]

Many loanwords were excluded to focus on morphologically simple words and loanwords borrowed specifically from English. Excluded categories included compound-like loanwords, truncated ones, and acronyms. Also excluded were loanwords derived from phrases, inflected words, or those with productive affixes, based on the English Phonology Search (Hayes 2011)[9]. To ensure focus on English-based loanwords, ones whose source words are not found in the Carnegie Mellon University (CMU) Pronouncing Dictionary (Weide 1994) or the Subtlex Corpus (Brybaert & New 2009) were excluded.[10] Additionally, loanwords whose adaptations could not be attributed to either auditory or orthographic borrowing from English (e.g., ^{4}[bɯ́i**j**on] rather than ^{4}[bɯ́i**l**on] for ‘bouillon’, ^{3}[montáːʑ<**ɯ**>] rather than ^{3}[montáːʑ<**i**>] for ‘montage’) were excluded, assuming that such loanwords were borrowed from languages other than English.

Additional loanwords were excluded from the analysis due to various reasons. First, loanwords from English words with two possible stress patterns, as determined by the English Phonology Search, were excluded (e.g., [ˈɪmˌpækt]~[ɪmˈpækt] ‘impact’ (noun vs. verb)). Second, loanwords with super-heavy syllables (i.e., sequences of a long vowel or a diphthong followed by a moraic nasal) were excluded (e.g., ^{3}[ɾáin] ‘line’), as there is no consensus on how they should be treated in Japanese accentuation. Third, loanwords with source words involving onset glides that were adapted into Japanese as a high vowel (e.g., ^{3}[**i**éɾoː] rather than ^{3}[**j**éɾoː] for ‘yellow’), or ones with source words containing onset palatal affricates/fricatives that were adapted with an inserted

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[7] They were counted separately because the analysis in this study focuses exclusively on syllable structures, grouping individual loanwords together. An analysis at the individual word level will be considered for future research.

[8] Although there are some disagreements in the literature (see Kubozono 2015), this study adopts the criterion that aims to establish a straightforward correspondence between English source words and loanwords.

[9] The program is based on a modified version of the CMU Pronouncing Dictionary. The data include all the words from CMU that have a CELEX frequency of at least 1.

[10] Despite this criterion, there is a possibility that some loanwords in the dataset may be borrowed from languages other than English. Nevertheless, in the context of this study’s focus on suprasegmental adaptation, the exposure of Japanese speakers to the English pronunciations of these words could still be a relevant factor, regardless of their original source. To enhance accuracy, future research could consider taking into account the lexical frequency of the source words as they are used in English.

[i] following them (e.g., ^{4}[maɾéːɕ**i**a] rather than ^{3}[maɾéːɕa] for ‘Malaysia’), were excluded, because the status of such loanword syllables is unclear (i.e., full or epenthetic). Finally, loanwords longer than four syllables were excluded, to maintain a manageable size for the models developed in Section 4. As a result, a total of 3,017 loanwords remained for data analysis.

Each loanword syllable was annotated as either primary stressed, secondary stressed, unstressed, or epenthetic, based on the CMU Pronouncing Dictionary and the English Phonology Search. In instances of discrepancies between these sources, the annotation from the English Phonology Search was followed. The data likely include both auditory and orthographic borrowings; distinguishing between these two can be challenging as they frequently overlap (Daland, Oh, & Kim 2015) and the distinction between them is probably not always categorical (Hamann & Colombo 2017).

3.2. Overview of the accent pattern in the corpus data

This section provides an overview of the accent patterns found in the corpus data, aiming to give a broad understanding of their distribution across syllable structures before delving into formal modeling. Note that for the reason of space, I will omit the description related to the unaccented pattern, as it is not the primary focus of this study (see the Appendix for more details). Here, loanwords are categorized as either bimoraic/trimoraic or longer. This distinction is necessary due to the limited accent patterns the former can exhibit. Additionally, longer loanwords are further classified based on the syllable structure of the final three moras (i.e., LH, HL, HH, LLL, HLL), which play a key role in determining loanword accent.

Let us begin with a straightforward generalization: *words consisting of two or three moras have an initial accent*. Out of 1087 words in this category, 72% (786 words) have an initial accent (e.g., ^{2}[bós<ɯ>] ‘boss’ ^{3}[kánada] ‘Canada’). In the case of the three-mora words, we may attribute this to the antepenultimate accent rule of McCawley (1968). Exceptions often involve an epenthetic vowel. Among the 26 LH words beginning with an epenthetic syllable, 73% (19 words) bear penultimate-mora accent (e.g., ^{2}[b<ɯ>ɾɯ́ː] ‘blue’, but ^{3}[p<ɯ́>ɾan] ‘plan’), consistent with Kubozono’s (2006) description.

Turning to words with more than three moras, they roughly fall into two categories. First, *words ending in HH or HLL typically obey the antepenultimate accent rule*, with 81% (419 out of 515 words) conforming to this pattern (e.g., ^{4}[bakéːɕon] ‘vacation’, ^{4}[hambáːgaː] ‘hamburger’). Second, *words ending in HL, LLL, or LH vary between antepenultimate-mora accent and pre-antepenultimate-mora accent*. This variation even extends to pre-pre-antepenultimate-mora accent, which places the accent on the syllable containing the mora located two positions prior to the antepenultimate one. More precisely, words ending in HL or LLL are more likely to bear antepenultimate-mora accent, with 56% (573 out of 1020 words) adhering to this accent pattern (e.g., ^{3}[konkóːs<ɯ>] ‘concourse’, ^{3}[t͡ɕokoɾéːt<o>] ‘chocolate’) and 28% (284 words) bearing (pre-)pre-antepenultimate-mora accent (e.g., ^{5}[táːminaɾ<ɯ>] ‘terminal’, ^{5}[ébidens<ɯ>] ‘evidence’). In contrast, words ending in LH more often bear (pre-)pre-antepenultimate-mora accent, with 26% (68 out of 395 words) following the antepenultimate accent rule (e.g., ^{3}[kaːdígan] ‘cardigan’, ^{3}[t<o>ɾadíɕon] ‘tradition’) and 66% (262 words) bearing (pre-)pre-antepenultimate-mora (e.g., ^{5}[háːmoniː] ‘harmony’, ^{5}[kjáɾak<ɯ>taː] ‘character’). The prevalence of pre-antepenultimate-mora accent in words ending in LH is consistent with the observations made by Katayama (1998) and Kubozono (2006).

Why do words ending in HH or HLL mostly bear antepenultimate-mora accent while ones ending in HL, LLL, or LH exhibit a mix of antepenultimate-mora accent and (pre-)pre-antepenultimate-mora accent? I suggest the following explanation. In the case of the former, faithfulness typically aligns with the antepenultimate accent rule. That is, the stress pattern of source words (cf. the Latin Stress rule in English) typically assigns stress on source syllables that correspond to loanword syllables including the antepenultimate mora. Indeed, this happens 92% of words in this category. On the other hand, for the latter structures, the Latin Stress rule often stresses source syllables that match loanword syllables including the (pre-)pre-antepenultimate mora. This pattern is observed in 92% of words ending in LH and 57% of ones ending with HL or LLL.[11] These proportions do not directly correspond to those of (pre-)pre-antepenultimate-mora accent in loanwords with these structures (92% vs. 66% for LH endings, and 57% vs. 28% for HL or LLL endings). This discrepancy arises because sometimes faithfulness to source words is respected, while at other times, the antepenultimate accent rule is followed. This conflict will be modeled in Section 4.

4. A MaxEnt analysis of loanword accentuation in Japanese

Section 3 revealed that the corpus data display a significant level of predictability (though not complete predictability), reflecting a statistical blend of conflicting patterns. Moving forward, I propose an explicit analysis using Maximum Entropy (MaxEnt) Harmonic Grammar (Goldwater & Johnson 2003, Hayes & Wilson 2008), which excels in modeling gradient data by assigning numerical weights to constraints rather than ranking them as in classical Optimality Theory (OT) (Prince & Smolensky 2004). MaxEnt generates a probability distribution over candidates and allows statistical evaluation of constraints’ explanatory power.

As a good starting point for my analysis, I adopt the classical OT analysis proposed by Ito and Mester (2016), which stands out as the most comprehensive and influential OT analysis of Japanese loanword accentuation presented to date.

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[11] For the former words, this is expected due to the light penultimate syllable ([…LH]). However, it is surprisingly prevalent in the latter words as well. In these cases, English source words often end in a coda consonant, resulting in an epenthetic syllable in loanwords ([…H<L>], […LL<L>]). As a result, stressed syllables in the source words often match with loanword syllables containing the (pre-)pre-antepenultimate mora.

4.1. Baseline model: Ito and Mester (2016)

In this section, I provide a brief overview of Ito and Mester's (2016) OT model and explain the adjustments I have made to adapt its structure to MaxEnt modeling.[12] Due to space limitations, I focus on the aspects most pertinent to the modeling process; readers should refer to their original paper for full details.

Ito and Mester's model employs syllable structures as inputs and logically possible foot structures as output candidates, under the three requirements outlined in (1). These are: (a) accents must align with the head syllable of the head foot; (b) every prosodic word must have at least one foot; and (c) feet can have a maximum of two syllables. In their notation, capital letters represent head syllables, and small capitals represent non-head syllables.

(1) Three requirements on the outputs
  a. If the prosodic word contains an accent, it must coincide with the head syllable of its head foot (e.g., ^{2}[L(ĹL)], ^{2}[(ĹL)] instead of (*^{3}[Ĺ(LL)], *^{1}[(LĹ)]).
  b. Headless forms are not qualified as candidates, i.e., a prosodic word contains at least one foot (e.g., ^{3}[(ĹL)L], ^{3}[(H́)L] instead of *^{3}[ĹLL], *^{3}[H́L]).
  c. Feet must be maximally binary at the level of the syllable (e.g., *^{3}[(ĹLL)], *^{0}[(HLL)]).

These requirements reflect three undominated constraints: WORD PROMINENCE TO WORD HEAD, HEADEDNESS, and the maximal version of FOOTBINARITY. In a best-fit MaxEnt model, these undominated constraints, which are never violated by winners, are assigned infinite weight, effectively nullifying the probability of any candidate violating them. This approach helps limit the number of candidates for computational consideration by excluding those that violate these undominated constraints.

To further streamline the output structure, my models also omit candidates that violate Ito and Mester's MORAICTROCHEE constraint, which is considered undominated in their analysis. This constraint disallows feet larger than two moras or with an iambic pattern (i.e., (HH), (HH), (HL), (HL), (LH), (LH), (LL)). Aligning with their approach, my models assume feet are maximally two moras and follow a trochaic pattern. Thus, I avoid using capital and small capital letters to differentiate head from non-head syllables, since all feet in my model are trochaic. For instance, (LL) consistently represents (LL) rather than (LL).

Ito and Mester rank ten markedness constraints (excluding MORAICTROCHEE) to capture markedness principles in loanword accentuation in Japanese. Table 1 details these constraints and their rankings, with definitions slightly modified for accessibility to those unfamiliar with Ito and Mester's analysis).

[12] The basic structure of the grammar was generated in Ito and Mester (2016) using OTWorkplace (https://sites.google.com/site/otworkplace/). Many thanks to Junko Ito and Armin Mester for providing me with their spreadsheet.

Stratum	Constraint: definition
1	a. **NONFINALITY(σ) (NONFIN(σ))** Word-final syllables are unparsed. b. **NOLAPSE** No consecutive syllables are unparsed. c. **MINIMALWORDACCENT (MINWDACC)** Minimal words (words consisting of at most two moras) have an accent. d. **RIGHTMOST** The head (accented) foot is the right most foot within the prosodic word.
2	e. **WEIGHT-TO-STRESS PRINCIPLE (WSP)** Heavy syllables are parsed into feet. f. **FOOTBINARITY (FTBIN)** Feet are minimally binary at some level of analysis (μ, σ).
3	g. **INITIALFOOT (INITFT)** Word-initial syllables are parsed into feet. h. **NONFINALITY (FT') (NONFIN(FT'))** The head (accented) foot does not contain the final syllable in the prosodic word.
4	i. **WORDACCENT (WDACC)** Prosodic words have an accent.
5	j. **PARSE-σ** Syllables are parsed into feet.

Table 1. Ito and Mester's (2016) constraint system (excluding MORAICTROCHEE)

Ito and Mester's model predominantly assigns antepenultimate-mora accent to accented loanwords, as depicted in the tableau shown in Table 2.

/banana/ ‘banana’		NoLapse	Rightmost	InitFt	NonFin(Ft’)	WdAcc	Parse-σ
☞	a. ^{3}[(bána)na]						*
	b. ^{0}[(bana)na]					*!	*
	c. ^{2}[ba(nána)]			*!	*		*
/baɾɯserona/ ‘Barcelona’							
☞	d. ^{3}[(baɾɯ)(séɾo)na]						*
	e. ^{0}[(baɾɯ)(seɾo)na]					*!	*
	f. ^{5}[(báɾɯ)(seɾo)na]		*!				*
	g. ^{2}[(baɾɯ)se(ɾóna)]				*!		*
	h. ^{5}[(báɾɯ)seɾona]	*!					***
	i. ^{4}[ba(ɾɯ́se)(ɾona)]		*!	*			*

Table 2. Sample tableau illustrating Ito and Mester’s prediction of antepenultimate-mora accent for loanwords with three and five light syllables (adapted from Ito and Mester 2016, p. 487).

The tableau shows that loanwords with three light syllables (represented by ^{3}[bánana] ‘banana’) and five light syllables (represented by ^{3}[baɾɯséɾona] ‘Barcelona’) bear antepenultimate-mora accent. In brief, this is due to the requirement that syllables are maximally parsed into feet, leaving the final syllable unparsed (i.e., ^{3}[(LL)L], ^{3}[(LL)(LL)L]).

The key aspect of Ito and Mester’s analysis is that the same ranked constraints result in the unaccented pattern for loanwords with four light syllables (i.e., LLLL) and ones ending in HLL syllables (i.e., […HLL]).[13] Table 3 includes a sample tableau for the LLLL structure (represented by ^{0}[ameɾika]).

[13] Ito & Mester’s (2016) analysis predicts the unaccented pattern for both four-mora words ending in LL (i.e., HLL, LLLL) and longer words ending in HLL (e.g., LHLL, HHLL). However, my corpus data (and Kubozono’s 2006 description) indicates this primarily applies to the former. Addressing this discrepancy could involve differentiating words longer than four moras, but that would necessitate an ad hoc constraint. Therefore, this paper does not formally address this issue.

/ameɾika/ ‘America’	NoLapse	Rightmost	InitFt	Nonfin(Ft’)	WdAcc	Parse-σ
☞ a. ^{0}[(ame)(ɾika)]					*	
b. ^{4}[(áme)(ɾika)]		*!				
c. ^{2}[(ame)(ɾíka)]				*!		
d. ^{4}[(áme)ɾika]	*!					**
e. ^{3}[a(méɾi)ka]			*!			**

Table 3. Sample tableau illustrating Ito and Mester’s prediction of the unaccented pattern for loanwords with four light syllables (adapted from Ito and Mester 2016, p. 486).

For loanwords with four light syllables (and ones ending in HLL), the optimal foot structure involves parsing the final four moras into bimoraic feet (i.e., ([(ame)(rika)]), due to the undominated status of NoLapse and the relatively high ranking of InitFt. Moreover, assigning accents critically violates either Rightmost (b. ^{4}[(áme)(ɾika)]) or Nonfin(Ft’) (c. ^{2}[(ame)(ɾíka)]), which take precedence over WdAcc, making the unaccented candidate (a. ^{0}[(ame)(ɾika)]) the optimal choice.

Finally, in Ito and Mester’s model, loanwords ending in LLH receive pre-antepenultimate-mora accent. Table 4 displays a sample tableau for this pattern (represented by ^{4}[dóɾagon]).

/doɾagon/ ‘dragon’	Nonfin(σ)	Rightmost	WSP	FtBin	InitFt	Nonfin(Ft’)	WdAcc	Parse-σ
☞ a. ^{4}[(dóɾa)gon]			*					*
b. ^{0}[(doɾa)(gon)]	*!						*	
c. ^{2}[(doɾa)(gón)]	*!					*		
d. ^{4}[(dóɾa)(gon)]	*!	*						
e. ^{3}[do(ɾá)gon]			*	*!	*			**

Table 4. Sample tableau illustrating Ito and Mester’s prediction of pre-antepenultimate-mora accent for loanwords with the LLH structure (adapted from Ito and Mester 2016, p. 505).

In this context, the undominated Nonfin(σ) constraint plays a crucial role. It disqualifies candidates with the final heavy syllable parsed (b. ^{0}[(doɾa)(gon)], c. ^{2}[(doɾa)(gón)], d. ^{4}[(dóɾa)(gon)]), making exhaustive footing suboptimal for these structures. Furthermore, FtBin rules out the candidate with antepenultimate-mora accent (e. ^{3}[do(ɾá)gon]), making the one with pre-antepenultimate-mora (a. ^{4}[(dóɾa)gon]) the optimal choice. My corpus data, along with descriptions by Katayama (1998) and Kubozono (2006), show that not only loanwords ending in LLH but also ones ending in HLH often bear pre-antepenultimate-mora accent (i.e., ^{4}[…ĹLH], ^{3}[…H́LH]). This minor discrepancy, however, is less significant in probabilistic models where constraints are not ranked. Additionally, the occurrence of pre-antepenultimate-mora accent can often be attributed to faithfulness effects to source words, as discussed in Section 3.2 above.

4.2. Expanding input structure

As in Ito and Mester's (2016) model, my MaxEnt models employ syllable structures as inputs. However, they require finer distinctions due to the integration of more factors. A key aspect is distinguishing loanword syllables based on their English source syllables: primary stressed (e.g., ˈL), secondary stressed (ˌL), unstressed (L), and epenthetic (<L>). Additionally, the models distinguish between syllables with devoiced vowels (L̥) and one with voiced vowels (L) and categorize heavy syllables by their gradient weight – those with an obstruent coda (labelled "G"), a nasal coda ("N"), or consisting of a long vowel/diphthong ("V") (e.g., ^{3}[k**áp**p<ɯ>] 'cup', ^{3}[d**án**s<ɯ>] 'dance', ^{3}[p**á**ːk<ɯ>] 'park'). The rationale for these distinctions will be outlined in Section 4.4.2. These distinctions lead to a total of 485 inputs, each representing at least one loanword in the corpus, and include 21,503 output possibilities. To enable direct comparisons among the models, this structure is maintained consistently across all model updates. The MaxEnt spreadsheet can be accessed on the OSF page.

As in Ito and Mester's (2016) model, the inputs in my models are based on segmentally adapted loanword forms rather than the original English source forms. This approach assumes that input forms already incorporate crucial segmental processes of loanword adaptation. Thus, symbols in the input (i.e., L, G, N, V, <L>) represent syllable types as they are adapted from source structures. The model also assumes the input forms encode certain native segmental processes. In the context of the present analysis, the only relevant process is high vowel devoicing (see Section 4.4.2). Hence, the symbol L̥ in the input denotes a source structure adapted as a light syllable in an environment where the process of high vowel devoicing is applicable.

4.3. Hidden structure

Given the learning data and a set of constraints, a MaxEnt model finds the constraint weights that minimize the difference between observed and predicted probabilities. As in Ito and Mester's (2016) model, each output in my models corresponds to a unique foot structure. However, these structures are not directly observable; learners infer them from accumulated surface accent patterns This is an instance of the "hidden structure" problem (e.g., Tesar & Smolensky 1998, Jarosz 2015). In addressing the hidden structure problem here, I assume that the learning data provided to my MaxEnt models only contain surface accent patterns of loanwords, devoid of any information about foot structure. For instance, instead of having access to representations like ^{3}[(bána)na] or

[3][(bá)nana], the models receive surface accent patterns such as [3][bánana]. This assumption is implemented by aggregating the predicted probabilities of all possible foot structures for the same surface accent pattern, following the method put forth by Moore-Cantwell (2020) in an analysis of English stress assignment. This approach ensures constraint weights are based on surface accents, reflecting data actually available to learners, while the model determines the distribution of probability across various foot structures.

4.4. Comparing a series of models

In this section, I examine a series of MaxEnt models, gradually integrating more factors into the Ito and Mester's baseline model. This baseline model undergoes three updates to include (i) additional markedness effects, (ii) faithfulness effects to source words, and (iii) faithfulness effects to native speakers' knowledge of the English stress system, termed the Japanese Theory of English. Each update is justified by improved model accuracy, evaluated using likelihood ratio tests (Wasserman 2004), with a significance level of 0.05. The difference in log likelihood between the full and subset models is denoted as Δ log likelihood. Additionally, the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) are presented for reference in a summary table (Table 5), although these metrics are not explicitly discussed. While the models are named after their newly added factors, all previously incorporated factors are retained upon integration; a final pruning of non-significant constraints is carried out in Section 4.4.5.

The loanwords from the corpus data are used as learning data for the models. To fit the constraint weights, I use the Excel Solver tool (Fylstra et al. 1998), which employs Conjugate Gradient Descent to find weights in a way as to maximize the likelihood of the model, under the condition that weights must be positive (act as penalties).

4.4.1. A MaxEnt version of Ito and Mester's model

The first model to examine is a probabilistic version of Ito and Mester's (2016) model. Column (a) in Table 5 presents the best-fit constraint weights (along with the log likelihood, AIC, and BIC) in this model. The log likelihood of the model, used as a benchmark for later models, is **-2221.48**.

Type		Constraint	Weight				
			(a) M1	(b) M2	(c) M3	(d) M4	(e) Final
I&M	Stratum 1	NonFinality(σ)	9.80	3.33	3.13	2.66	2.63
		NoLapse	0.36	0.00	0.00	0.00	
		MinimalWordAccent	4.57	4.08	4.00	3.71	3.76
		Rightmost	0.77	1.83	1.54	1.68	1.67
	Stratum 2	WSP	7.94	0.00	0.00	0.00	
		FootBinarity	1.82	1.78	1.44	1.18	1.19
	Stratum 3	InitialFoot	0.00	0.47	0.14	0.00	
		NonFinality(Ft')	3.18	2.90	3.23	3.17	3.13
	Stratum 4	WordAccent	1.98	2.08	2.53	2.85	2.83
	Stratum 5	Parse-σ	0.94	0.18	1.18	1.56	1.50
Additional Markedness		WSP(G)		**0.00**	0.00	0.00	
		WSP(N)		**0.36**	0.30	0.16	
		WSP(V)		**2.02**	1.62	1.15	1.15
		*DevoicedAccent		**2.09**	1.22	1.21	1.22
Faithfulness		Dep[Accent]			**0.45**	0.48	0.72
		Dep[Accent](PS)			**0.54**	0.27	
		Dep[AccentedV]			**0.59**	1.02	1.05
JTOE		Faith-JTOE[Accent]				**0.98**	1.02
Log likelihood			-2221.48	-2147.72	-2007.65	-1982.28	-1984.08
AIC			4462.96	4323.43	4049.29	4000.56	4004.17
BIC			4523.08	4407.60	4151.50	4108.78	4112.39

Table 5. Best-fit constraint weights, log likelihood, AIC, and BIC for a series of MaxEnt models: (a) M1, the MaxEnt version of Ito and Mester's model; (b) M2, the augmented Ito-Mester model; (c) M3, the faithfulness model; (d) M4, the JTOE model; and (e) the final model.

Many constraints received weights, indicating their relevance. However, the weight distribution does not fully mirror the constraint system in Ito and Mester's categorical model. Notably, NoLapse and Rightmost received relatively small weights (0.36 and 0.77), despite being undominated in their original model. The small weight for NoLapse may be due to its overlap with the broader Parse-σ constraint, but there is also an empirical reason. The corpus study uncovered abundant cases of (pre-)pre-antepenultimate-mora accent that are not predicted by Ito and Mester's model. These instances necessarily violate either NoLapse or Rightmost (e.g., ^{5}[(kón)saːt<o>] or ^{5}[(kón)(saː)t<o>] 'concert'). To allocate some probabilities to such accent patterns, the model requires smaller best-fit weights for these constraints. Additionally, InitFt received a zero weight. Since the primary role of this constraint is to ensure exhaustive footing for four-mora structures ending in LL, which is crucial for rendering them unaccented (e.g., ^{0}[(LL)(LL)], ^{0}[(H)(LL)]), the absence of weight for this constraint suggests potential inaccuracies in predicting the unaccented pattern, as discussed in the following paragraph.

Figure 1 compares observed corpus probabilities with those predicted by the MaxEnt version of Ito and Mester's model. Each datapoint represents a surface accent pattern for an input with foot structures collapsed as detailed in Section 4.3. To minimize bias from rare patterns, only inputs with at least five individual words are included in these scattergrams and subsequent ones. The left panel shows aggregate results, while the right panel breaks down the data by accent patterns (Pre2 = pre-pre-antepenultimate-mora, Pre = pre-antepenultimate-mora, Ant = antepenultimate-mora, Pen = penultimate-mora, Ult = ultimate-mora, Un = unaccented). The broad scatter of datapoints indicates the model's limitations in capturing certain accent patterns in the corpus data. Notably, it tends to underpredict the accent patterns that are not predicted by Ito and Mester's original model, especially certain instances of (pre-)pre-antepenultimate-mora accent, while overpredicting antepenultimate-mora accent. The model also tends to underpredict the unaccented pattern.

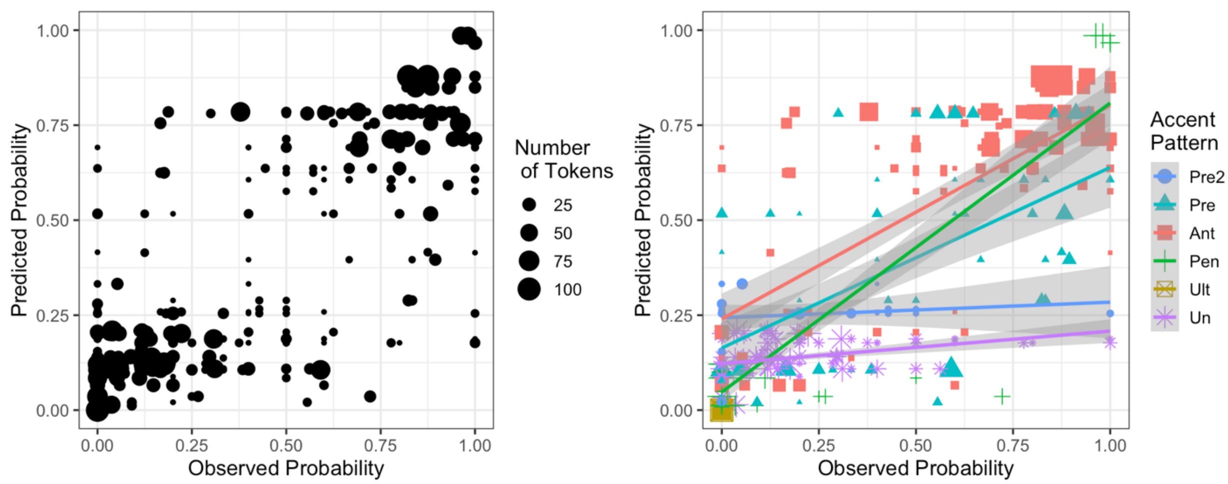

Figure 1. Comparison of observed probabilities from corpus data with predicted probabilities from the MaxEnt version of Ito and Mester's model.

4.4.2. Augmented Ito-Mester model

The second probabilistic model incorporates two additional markedness effects. First, it addresses vowel devoicing in Japanese, where high vowels /i, ɯ/ typically devoice between voiceless consonants (e.g., ^{0}[ɕi̥ka] 'deer') (McCawley 1968)[14] and are less likely to carry an accent (e.g., ^{2}[s<ɯ̥>pín] 'spin') (McCawley 1977, Haraguchi 1991, Tsuchida 1997, 2001). Second, it accounts for the finer differences in heavy syllables (i.e., G, N, V), recognizing that syllable weight can be gradient rather than binary (i.e., L vs. H) (Gordon 2002, 2007, Ryan 2011). This update is crucial for accurately evaluating faithfulness effects in subsequent models. Notably, it is essential to represent vowel devoicing accurately to assess the impact of epenthetic vowels, given many devoiced vowels are epenthetic.

[14] While High vowels can also devoice after a voiceless consonant word-finally (e.g., wasi [waɕi̥] 'hawk') (McCawley 1968), I dispense with this environment, because it may be a phrasal process (Kilbourn-Ceron & Sonderegger 2018) and final light syllables in loanwords do not bear an accent in any event.

I formalize the effect of devoiced vowels (a) and that of gradient syllable weight (b-d) in (2). The former constraint is equivalent to *ACCENTED[+S.G.] in Tsuchida (1997, 2001), but its name has been altered within the context of this study.

(2) Additional markedness constraints
   a. *DEVOICEDACCENT (*DEVACC): Syllables with a devoiced vowel must not be accented.
   b. WSP(G): Heavy syllables consisting of a vowel plus an obstruent coda (i.e., the first element of a geminate) are parsed into a foot.
   c. WSP(N): Heavy syllables consisting of a vowel plus a nasal coda are parsed into a foot.
   d. WSP(V): Heavy syllables consisting of a long vowel or a diphthong are parsed into a foot.

Column (b) in Table 5 shows the best-fit constraint weights in the augmented Ito-Mester model. *DEVACC received a weight of 2.09, confirming the tendency for syllables with devoiced vowels to avoid accent. The gradient versions of WSP received varying weights based on sonority: WSP(V) is high (2.02), WSP(N) is small (0.36), and WSP(G) is zero. This leads to the weight of the original WSP constraint dropping to zero, indicating that the primary effect of WSP arises from heavy syllables with long vowels or diphthongs. Likelihood ratio tests confirm each of these additions significantly improves the model's fit (*DEVACC: Δ log likelihood = 43.75, $p < 0.001$; WSP(G/N/V): Δ log likelihood = 29.73, $p < 0.001$). The log likelihood of the model improved to **-2147.72** from -2221.48 (Δ log likelihood = 73.76) in the previous model.

Figure 2 shows the predicted versus observed plot from the augmented Ito-Mester model. While the correlation has improved, the same issues remain: underprediction of (pre-)pre-antepenultimate-mora accent and the unaccented pattern, and overprediction of antepenultimate-mora accent.

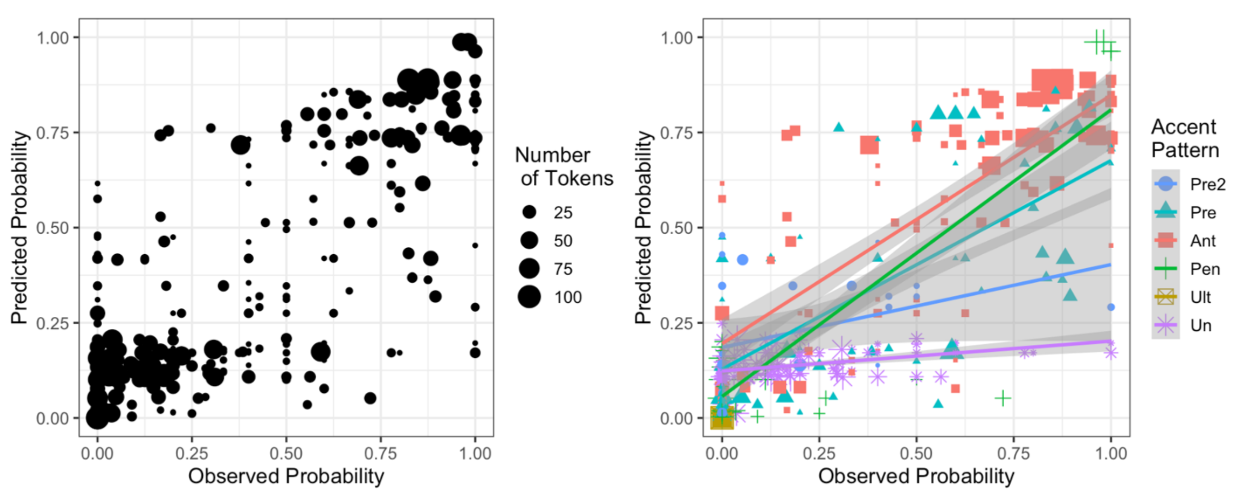

Figure 2. Comparison of observed probabilities from corpus data with predicted probabilities from the augmented Ito-Mester model.

4.4.3. Faithfulness model

The next step involves adding faithfulness effects to the enriched markedness system. This process takes into account non-native phonological properties in loanword adaptation, including English stress, consonant clusters, and word-final (non-nasal) consonants, the latter two of which result in epenthetic syllables in loanword forms (e.g., /pleɪ/ → ^{2}[p**<ɯ>**ɾéi] 'play', /ʃɑp/ → ^{3}[ɕópp**<ɯ>**] 'shop'; note that placing an accent on word-final light syllables is highly marked in any case).

To formalize the faithfulness effects, I introduce three loanword-specific faithfulness constraints that govern the correspondence between English source words and their loanword counterparts, as shown in (3). Dep[Acc] (a) and Dep[Acc](PS) (b) examine the effect of stress in general and that of primary stress specifically. Note that violating the latter constraint implies violating the former as well. Dep[Acc](PS) corresponds to FaithLoc(Accent) in Mutsukawa (2005, 2006). To my knowledge, however, the broader effects of stress (encompassing both primary and secondary) have not been explored in Japanese loanword accentuation. Dep[V́] (c) assesses the claimed tendency of epenthetic syllables to avoid carrying an accent. This is analogous to *v (epenthetic vowel) or Head(Foot)-Dep introduced in the context of Japanese speakers' online adaptation of French words in Shinohara (2000, 2004).

(3) Faithfulness constraints

a. Dep[Accent]: Do not assign accent on loanword syllables that correspond to unstressed syllables in English source words (e.g., violated by /bəˈnænə/ → ^{3}[bánana] 'banana', but not violated by /ˈɛpɪˌsoʊd/ → ^{3}[episóːd<o>] 'episode')
b. Dep[Accent](PrimaryStress) (Dep[Acc](PS)): Do not assign accent on loanword syllables that correspond to either secondary stressed or unstressed syllables in English source words (e.g., violated by both /bəˈnænə/ → ^{3}[bánana] 'banana' and /ˈɛpɪˌsoʊd/ → ^{3}[episóːd<o>] 'episode')
c. Dep[AccentedVowel] (Dep[V́]): Do not assign accent on epenthetic syllables (e.g., violated by /plʌs/ → ^{3}[p<ɯ́>ɾas<ɯ>] 'plus')

Column (c) in Table 5 presents the best-fit constraint weights in the faithfulness model. Dep[Acc] received a weight of 0.45, indicating loanword syllables corresponding to English stressed syllables (either primary or secondary) attract accent. Dep[Acc](PS) received a weight of 0.54 on top of Dep[Acc], indicating a stronger effect of primary than secondary stress (this result turns out to be less compelling than it may initially appear, however; see Section 4.4.4). Dep[V́] received a weight of 0.59, confirming the tendency for epenthetic syllables to avoid accent. Notably, the inclusion of Dep[V́] reduced the weight of *DevAcc from 2.09 to 1.20, reflecting the overlap between devoiced and epenthetic syllables. Likelihood ratio tests confirm that each faithfulness constraint significantly improves the model's fit (Dep[Acc]: Δ log likelihood = 4.32, $p < 0.005$; Dep[Acc](PS): Δ log likelihood = 7.59, $p < 0.001$; Dep[V́]: Δ log likelihood = 7.27, $p < 0.001$). The log likelihood of the model increases to **-2007.65** from -2147.72 in the augmented

Ito-Mester model (Δ log likelihood = 140.07), indicating a significant improvement of the model's fit to the observed data.

Figure 3 displays the predicted versus observed plot from the faithfulness model. It demonstrates significantly improved correlation, effectively addressing previous inaccuracies, including the underprediction of (pre-)pre-antepenultimate-mora accent and the overprediction of antepenultimate-mora accent. The reason for this improvement was given above in Section 3.2: in many syllable structures the observed accent patterns reflect a stochastic conflict of markedness and faithfulness principles. However, the underprediction of the unaccented pattern persists.

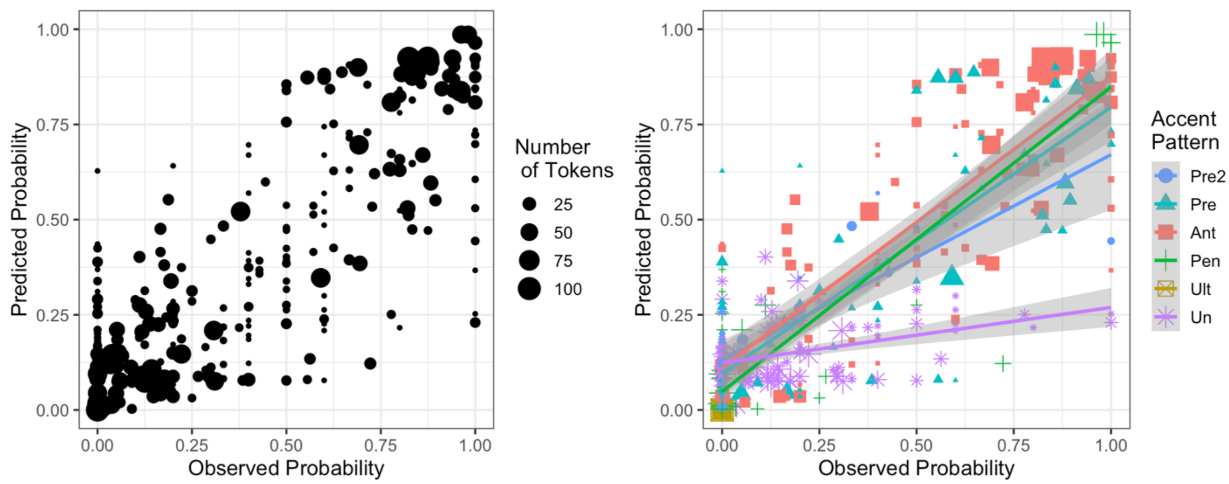

Figure 3. Comparison of observed corpus probabilities with predicted probabilities from the faithfulness model.

4.4.4. JTOE model

Identifying a tendency for English loanwords to preserve the stress patterns of their source words prompts an additional question: beyond merely replicating the stress patterns of individual source words, do Japanese speakers also internalize these stress patterns and apply this knowledge in the adaptation of certain English words? Specifically, when the stress patterns of English words are atypical, do Japanese speakers assign accents that align with the general stress patterns of English, in a manner that cannot be accounted for by markedness principles? This section demonstrates that this aspect does indeed have a discernible impact on the accentuation of loanwords in Japanese.

Research indicates that even limited exposure to a foreign language enables speakers to develop sophisticated phonotactic knowledge of that language. For example, Oh et al. (2020) and Panther et al. (2023) revealed that New Zealanders who do not speak Māori but are extensively exposed to it can evaluate the well-formedness of Māori-like nonwords just as well as fluent Māori speakers. In the context of loanword adaptation, the influence of borrowers' knowledge of the source language phonology, especially knowledge of its phonotactics, has been relatively understudied. An exception is the work of Kang, Phạm, and Storme (2014), who highlight the significance of this factor in the context of Vietnamese speakers adapting French words.[15] Given a high exposure of Japanese speakers to English, it is plausible that Japanese speakers develop phonotactic knowledge of English, including stress patterns. I refer to this knowledge as the "Japanese Theory of English" (JTOE). Hence, the model that incorporates this component is referred to as the JTOE model.

One anecdotal source of evidence for such a theory is a process called "hyperforeignization" (Janda et al. 1992), where speakers overapply patterns from known non-native forms to novel ones. For example, English speakers often stress the penultimate syllable in borrowed words, regardless of their original pronunciation. Notable cases include pronouncing the Japanese place name *Nagasaki* as [ˌnɑgəˈsɑki] and the Italian name *Cristofori* as [ˌkɹɪstəˈfoʊɹi], even though the former has antepenultimate-mora accent in Japanese (^{3}[nagásaki]) and the latter has stress on the antepenultimate syllable in Italian ([kriˈstɔːfori]). In these examples, English speakers overapply the penultimate stress rule, which likely is induced by their exposure to Spanish (and Italian) words ending with a light syllable, in loanwords borrowed from Japanese and Italian.

Japanese speakers, too, appear demonstrate hyperforeignisms. Table 6 presents loanwords with (pre-)pre-antepenultimate-mora accent that deviate from the stress patterns of their source words, leading to their underprediction in the faithfulness model. Crucially, these accent patterns are also not accounted for by the markedness effects as assumed in this study. A detailed examination of the data indicates that their accent patterns mirror typical English stress patterns. This section focuses on modeling the effect of JTOE and its role in improving the accuracy of our loanword accentuation model.

[15] In French, the distribution of mid vowels is governed by a phonotactic restriction, known as the *Loi de Position* (Féry 2003; Storme 2017): lax vowels (/ɛ, œ, ɔ/) usually occur in closed syllables, while tense vowels (/e, ø, o/) appear in open syllables, with some exceptions. They argue that Vietnamese speakers' (imperfect) knowledge of this restriction influences their adaptation of French mid vowels into Vietnamese.

Input	Output	English	Japanese
/Lˈ G<L>/	^{4}[ĹG<L>]	Quebéc Tibét duét baróque boutíque	^{4}[kébekk<ɯ>] ^{4}[t͡ɕíbett<o>] ^{4}[djɯ́ett<o>] ^{4}[báɾokk<ɯ>] ^{4}[bɯ́tikk<ɯ>]
/ˌLˈ G<L>/	^{4}[ĹG<L>]	bàguét	^{4}[bágett<o>]
/Lˈ GL/	^{4}[ĹGL]	Morócco regátta risótto	^{4}[móɾokko] ^{4}[ɾégatta] ^{4}[ɾízotto]
/Nˈ N<L>/	^{5}[ŃN<L>]	consént	^{5}[kónsent<o>]
/Vˈ G<L>	^{5}[V́G<L>]	roulétte	^{5}[ɾɯ́ːɾett<o>]
/ˌVˈ G<L>/	^{5}[V́G<L>]	Gèorgétte	^{5}[d͡ʑóːzett<o>]
/Vˈ N<L>/	^{5}[V́N<L>]	Vermónt	^{5}[báːmont<o>]
/Lˈ LL<L>/	^{4}[ĹLL<L>]	inítial Carácas Seáttle delícious	^{4}[íniɕaɾ<ɯ>] ^{4}[káɾaka<ɯ>] ^{4}[ɕíatoɾ<ɯ>] ^{4}[déɾiɕas<ɯ>]
/Lˈ LL̥<L>/	^{4}[ĹLL̥<L>]	oásis	^{4}[óaɕi̥s<ɯ>]
/Lˈ L̥L<L>/	^{4}[ĹL̥L<L>]	offícial	^{4}[óɸi̥ɕaɾ<ɯ>]
/Nˈ LL<L>/	^{5}[ŃLL<L>]	Antáres	^{5}[ántaɾes<ɯ>]
/ˌNˈ LL<L>/	^{5}[ŃLL<L>]	Hòndúras	^{5}[hónd͡ʑɯɾas<ɯ>]
/ˌLLˈ G<L>/	^{6}[ĹLG<L>]	cìgarétte sìlhouétte mìnuét	^{6}[ɕígaɾett<o>] ^{6}[ɕíɾɯett<o>] ^{6}[ménɯett<o>]
/ˌL<L>ˈ G<L>/	^{6}[Ĺ<L>G<L>]	qùartét tèchníque	^{6}[káɾ<ɯ>tett<o>] ^{6}[ték<ɯ>nikk<ɯ>]
/ˌL<L>ˈ GL/	^{6}[Ĺ<L>GL]	fàlsétto	^{6}[ɸáɾ<ɯ>setto]
/L<L̥>ˈ N<L>/	^{6}[Ĺ<L̥>N<L>]	suspénse	^{6}[sás<ɯ̥>pens<ɯ>]
/L<L̥>ˈ V<L>/	^{6}[Ĺ<L̥>V<L>]	excíte	^{6}[ék<i̥>sait<o>]
/ˌVˈ LG<L>/	^{6}[V́LG<L>]	òrgánic	^{6}[óːganikk<ɯ>]
/Vˈ LN<L>/	^{6}[V́LN<L>]	Wyóming	^{6}[wáiomiŋg<ɯ>]

Table 6. Instances of potential hyperforeignisms with (pre-)pre-antepenultimate-mora accent, unsupported by either faithfulness to source words or markedness principles.

To integrate the effect of JTOE, we start by creating a preliminary model of it. The goal here is to develop a model that reasonably represents Japanese speakers' knowledge of the English stress system, although what exactly such a model should look like must be established empirically. The aim is not to construct an exhaustive model of the English stress system itself, as that would exceed the scope of this study. For this purpose, I modify an existing MaxEnt model of English stress by ANONYMOUS (2018), designed for a class exercise. This model predicts primary stress in about 12,600 English words based on their syllabic and segmental structures, using 28 constraints, mostly extracted from the literature on English stress (e.g., Chomsky & Halle 1968, Liberman & Prince 1977, Hayes 1982).

Unlike my MaxEnt models, which use syllable structures as inputs, the English stress model takes individual words as inputs. As a result, some of the constraints in the model refer to specific types of segments or morphemes. I removed those constraints from the model as they are likely too detailed for the JTOE. For instance, in the original model by ANONYMOUS, a constraint requiring penultimate stress when the final syllable has a palate-alveolar onset receives a substantial weight (e.g., [ɪˈnɪɕəl] 'initial', [dɪˈlɪɕəs] 'delícious'). However, such detailed constraints are unlikely to be internalized by Japanese speakers, as suggested by adaptations like ^{4}[íniɕaɾ<ɯ>] and ^{4}[déɾiɕas<ɯ>]. Another crucial difference from my models is that the English stress model does not presuppose separate foot structures for each stress pattern. Therefore, the number of outputs for each input equals the number of stress patterns (or syllables) in the input.

In addition, I replaced the original SupHFin constraint, which requires stress on any word-final superheavy syllables, with three specific constraints: SupH(vvc)Fin, SupH(vnc)Fin, SupH(vcc)Fin, as shown in (4h-j). These differentiate between the three types of super-heavy syllables in English: vvc, vnc, and vcc (where "v" is a vowel, "n" a nasal coda, and "c" a non-nasal coda). These distinctions were made because inputs in my MaxEnt models distinguish corresponding adapted forms in Japanese: V<L>, N<L>, L<L><L>. This modification not only aligns the structure of JTOE with my models but also improves the accuracy of the English stress model, highlighting the significance of differentiating these superheavy syllables in English stress. Notably, the greater weight assigned to SupH(vvc)Fin over SupH(vnc)Fin (2.97 vs. 1.53) mirrors the similar weight difference between WSP(V) and WSP(N), as discussed in Section 4.4.2.

Following these modifications, a total of 10 constraints remained, as presented in (4). I ran the model with the revised constraint set, allowing the weights to be negative (act as rewards) as well as positive. The constraint weights in the best-fit model are also included in (4).

(4) Constraints employed in the revised English stress grammar and their weights

a. ***SkipHeavy:** Do not stress the antepenult if the penult is heavy
(based on Hayes 1982), *w* = 1.47

b. **NonFin:** Do not stress the final syllable
(based on Prince & Smolensky 2004), *w* = 2.18

c. **NonFinPoly:** Do not stress the final syllable of a word of more than two syllables
(not found in existing literature), *w* = 1.73

d. **AlignR-2:** Keep the stress within two syllables of the end of the word[16]
(based on Liberman & Prince 1977), *w* = -1.23

e. **AlignR-3:** Keep the stress within three syllables of the end of the word
(Liberman & Prince 1977), *w* = 2.29

f. **AlignR-4:** Keep the stress within four syllables of the end of the word
(Liberman & Prince 1977), *w* = 2.44

g. **FtBinFin:** Do not have stress on a light syllable in final position
(based on Selkirk 1984), *w* = 1.83

h. **SupH(vvc)Fin:** Words ending in VC must have final stress
(based on Chomsky & Halle 1968), *w* = 2.97

i. **SupH(vnc)Fin:** Words ending in NC must have final stress
(Chomsky & Halle 1968), *w* = 1.53

j. **SupH(vcc)Fin:** Words ending in VCC must have final stress
(Chomsky & Halle 1968), *w* = 2.29

The next step involved calculating the probabilities of stress patterns for English source words in my corpus data. To do this, I established assumptions about how English syllables typically adapted into Japanese, as shown in Table 7.[17] In brief: English light syllables are adapted as Japanese light syllables (i.e., L → L), heavy syllables as Japanese heavy syllables with a nasal coda or a long vowel/diphthong (i.e., H → N/V), sequences of a heavy syllable with an obstruent coda and an epenthetic syllable (i.e., H → G<L>), or ones of a light syllable and an epenthetic syllable (i.e., H → L<L>). English super-heavy syllables are adapted as Japanese super-heavy syllables (i.e., S → S) (note that loanwords containing a super-heavy syllable are not included in the current analysis), sequences of a heavy syllable with a long vowel/diphthong and any number of epenthetic syllables (i.e., S → V<L>), ones of a heavy syllable with a nasal coda and any number of epenthetic syllables (i.e., S → N<L>), or ones of a light syllable and more than one epenthetic syllables (i.e., S → L<L><L>).

[16] A negative weight assigned to this constraint reflects a preference for the antepenultimate stress, as in [ˈkænədə] ‘Canada’.

[17] Weight of English syllables is determined based on the standard assumption in the literature, where syllables with a short vowel are classified as light (i.e., L), ones with a long vowel, a diphthong, or a short vowel followed by a coda consonant are considered heavy (H), and ones with both a long vowel or a diphthong followed by a coda consonant and ones with a short vowel followed by two coda consonants are classified as superheavy (S) (e.g., Gordon 2007).

English → Japanese	Example
a. L → L	[kænədə] → [kanada] ‘Canada’
b. H → N/V	[taɪ] → [tai] ‘tie’
c. H → G<L>	[gæp] → [gjapp<ɯ>] ‘gap’
d. H → L<L>	[dæm] → [dam<ɯ>] ‘dam’
e. S → S	[laɪn] → [ɾain] ‘line’
f. S → V<L>, V<L><L>	[aɪs] → [ais<ɯ>] ‘ice’
g. S → N<L>, N<L><L>	[dæns] → [dans<ɯ>] ‘dance’
h. S → L<L><L>, L<L><L><L>	[gɑlf] → [goɾ<ɯ>ɸ<ɯ>] ‘golf’

Table 7. General assumptions on how English syllables are adapted into Japanese.

Using these assumptions, I inferred the syllable structures of English source words from their adapted loanword forms. Note that the inferred structures may differ from the actual English structures, as real-world adaptations do not always follow these assumptions. For instance, orthographic adaptations like *oasis* → ^{4}[óaɕis<ɯ>] may deviate: the inferred structure (LLH) differs from the actual structure (HHH based on /oʊˈeɪsɪs/). In fact, such deviation is favorable as it seems to better reflect how Japanese speakers infer the source pronunciations of orthographic borrowings. That is, they would not typically infer /oʊˈeɪsɪs/ from the orthographic form *oasis*; the conjectured pronunciations, while probably varying among individuals, are likely to align more closely with the adapted Japanese form rather than the actual English pronunciation in terms of the syllable structure.

Using this approach, I compiled conjectured English syllable structures derived from the adapted Japanese forms. These syllable structures were then input into the best-fit English stress model (i.e., JTOE), which returned probabilities for stress patterns based on their violation profiles. Table 8 shows these predicted probabilities. Note that σs in these structures represent any syllable type, and any number of consonants can precede or intervene between syllables to form consonant clusters, which result in epenthetic syllables in loanword forms. While a thorough evaluation of the English stress model is not the focus here, readers familiar with the literature on English stress probably recognize that the highest probabilities (highlighted in bold) are assigned to the patterns expected from the existing literature. Indeed, we observe that these patterns generally align with the Latin Stress rule, although they are expressed as probabilistic tendencies.

English structure	Predicted probability					Example
	ˈσσσσσ	…ˈσσσσ	…ˈσσσ	…ˈσσ	…ˈσ	
σL				**0.98**	0.02	/ˈdeɪtə/ ‘data’
σH				**0.90**	0.10	/ˈsizən/ ‘season’
σS(VNC)				**0.66**	0.34	/ˈsɛntəns/ ‘sentence’
σS(VVC)				0.31	**0.69**	/beɪˈɹut/ ‘Beirut’
σS(VCC)				0.47	**0.53**	/bɝˈlɛsk/ ‘burlesque’
σLL			**0.77**	0.23	0.00	/ˈkænədə/ ‘canada’
σLH			**0.77**	0.23	0.00	/ˈænəməl/ ‘animal’
σHL			0.44	**0.56**	0.00	/bəˈzukə/ ‘bazooka’
σHH			0.44	**0.55**	0.01	/pɚˈkʌʃən/ ‘percussion’
σLS(VNC)			**0.76**	0.22	0.02	/ˈɛvədəns/ ‘evidence’
σLS(VVC)			**0.71**	0.21	0.08	/ˈɛpɪˌsoʊd/ ‘episode’
σLS(VCC)			**0.74**	0.22	0.04	/ˈɛvɛɹəst/ ‘Everest’
σHS(VNC)			0.42	**0.53**	0.05	/pɚˈfɔɹməns/ ‘performance’
σσLL		0.02	**0.76**	0.22	0.00	/əˈmɛrɪkə/ ‘America’
σσHL		0.01	0.43	**0.55**	0.00	/ˌpɛɹəˈnoɪə/ ‘paranoia’
σσLH		0.02	**0.75**	0.22	0.00	/əˈkædəmi/ ‘academy’
σσHH		0.01	0.45	**0.55**	0.01	/ˌænəˈmeɪʃən/ ‘animation’

Table 8. JTOE probabilities for English stress patterns (the dominant stress pattern in each phonological shape is shown in bold).

The final step integrates the faithfulness effects to the outputs of JTOE. To this end, I formalize FAITH-JTOE[ACC] as defined in (5). This constraint serves as a bias towards accent patterns that align with the dominant stress patterns in English, by penalizing deviations from JTOE probabilities.

(5) FAITH-JTOE[ACCENT] (FAITH-JTOE[ACC]): Do not deviate from the JTOE. Specifically, assign one minus JTOE probability for each accent.

Table 9 illustrates how violations of FAITH-JTOE[ACC] are assigned to candidates of the input /LˈLL<L>/ (e.g., /ɕiˈatoɾ<ɯ>/ ‘Seattle’), along with violations of the faithfulness constraints (DEP[ACC] and DEP[ACC](PS) are collapsed into DEP[ACC] as they assign the same violations in this example). In this sample tableau, candidates sharing the same surface accent are collapsed for the sake of simplicity.

Input: /LˈLL<L>/ /ˈLLL<L>/$_{\text{JTOE}}$: 0.77 /LˈLL<L>/$_{\text{JTOE}}$: 0.23 /LLˈL<L>/$_{\text{JTOE}}$: 0.00	Faith-JTOE[Acc]	Dep[Acc]	Dep[V́]
Pre: ^{4}[ĹLL<L>]	0.23	1	
Ant: ^{3}[LĹL<L>]	0.77		
Pen: ^{2}[LLĹ<L>]	1.00	1	
Ult: ^{1}[LLL<Ĺ>]			1
Un: ^{0}[LLL<L>]			

Table 9. Sample tableau illustrating how violations of Faith-JTOE[Acc] are assigned to the candidates of the input /LˈLL<L>/.

JTOE probabilities indicate that antepenultimate stress (/ˈLLL<L>/) is the most common (0.77), with penultimate stress (/LˈLL<L>/) being less frequent (0.23), and ultimate stress (/LLˈL<L>/) being nonexistent (0.00) in the data. The Faith-JTOE[Acc] violations are calculated as the difference between one and the JTOE probability for each accent pattern, resulting in violation scores of 0.23 for pre-antepenultimate-mora accent, 0.77 for antepenultimate-mora accent, and 1.00 for penultimate-mora accent. This creates a conflict between Dep[Acc] constraints, favoring antepenultimate-mora accent, and Faith-JTOE[Acc], favoring pre-antepenultimate-mora accent. Candidates with ultimate-mora accent and unaccented ones do not violate Faith-JTOE[Acc], but their probabilities are reduced as necessary by Dep[V́] and WdAcc, respectively.

Column (d) in Table 5 shows the best-fit constraint weights in the JTOE model. As the table shows, Faith-JTOE[Acc] received a weight of 0.98. Note that this addition results in decrease of Dep[Acc](PS) from 0.54 in the faithfulness model to 0.27, as Faith-JTOE[Acc] partly absorbs the effect of Dep[Acc](PS) (i.e., because the JTOE is often correct). The log likelihood of the model increases to **-1982.28**, from -2007.65 in the faithfulness model (Δ log likelihood = 25.36). A likelihood ratio test confirms that the inclusion of this constraint significantly enhances the model's fit to the data ($p < 0.001$).

Figure 4 shows the predicted versus observed plot based on the JTOE model. The correlation becomes even stronger, although the model continues to underpredict the unaccented pattern.

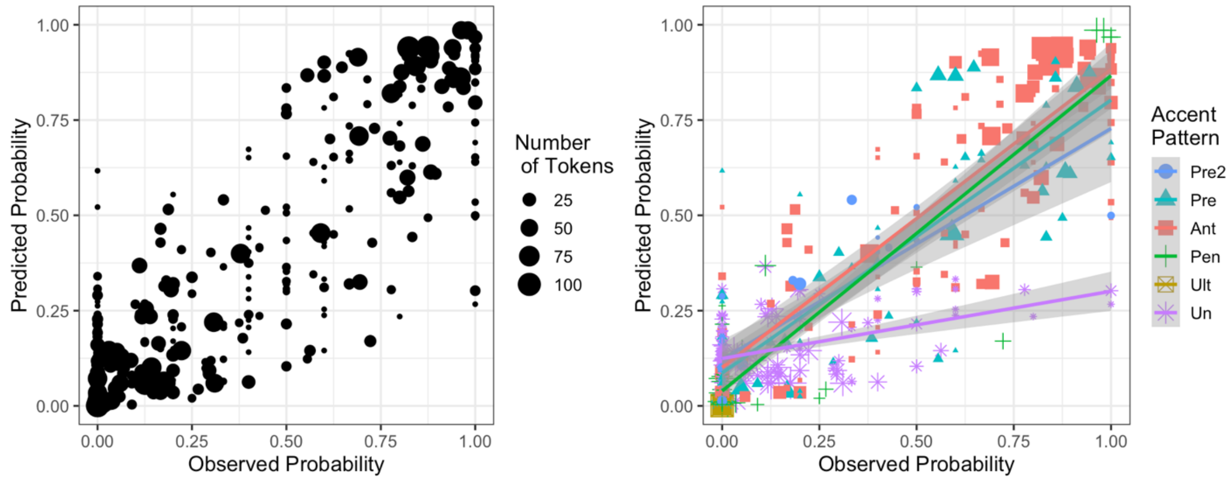

Figure 4. Observed probabilities based on the corpus data versus predicted probabilities based on the JTOE model.

Finally, Table 10 compares the observed and predicted probabilities for the accent patterns of potential hyperforeignisms (from Table 6) in the faithfulness and JTOE models. Inputs with only one actual word were excluded to avoid overestimating observed probabilities. The table reveals that the faithfulness model underpredicts all accent patterns, while the JTOE model reduces this underprediction, albeit not completely.

Input	Output	Observed probability	Predicted probability	
			Faithfulness	JTOE
/LˈG<L>/	^{4}[ĹG<L>]	0.38	0.08	0.18
/ˌLˈG<L>/	^{4}[ĹG<L>]	0.50	0.12	0.26
/LˈGL/	^{4}[ĹGL]	0.60	0.08	0.15
/VˈN<L>/	^{5}[V́N<L>]	0.33	0.13	0.17
/LˈLL<L>/	^{4}[ĹLL<L>]	0.40	0.27	0.37
/LˈLL̥<L>/	^{4}[ĹLL̥<L>]	0.50	0.29	0.40
/NˈLL<L>/	^{5}[ŃLL<L>]	0.50	0.13	0.21
/ˌNˈLL<L>/	^{5}[ŃLL<L>]	0.50	0.19	0.30
/ˌLLˈG<L>/	^{6}[ĹLG<L>]	0.60	0.19	0.32
/ˌL<L>ˈG<L>/	^{6}[Ĺ<L>G<L>]	0.50	0.19	0.34
/L<L̥>ˈN<L>/	^{6}[Ĺ<L̥>N<L>]	0.50	0.12	0.16
/L<L̥>ˈV<L>/	^{6}[Ĺ<L̥>V<L>]	0.25	0.06	0.07
/ˌVˈLG<L>/	^{6}[V́LG<L>]	0.50	0.25	0.32
/VˈLN<L>/	^{6}[V́LN<L>]	0.50	0.16	0.22

Table 10. Observed probabilities for accent patterns of potential hyperforeignisms from Table 6 (excluding inputs with only one word), compared with predictions from the faithfulness and JTOE models.

4.4.5. Final model

This section presents the final model of loanword accentuation in Japanese, removing constraints whose contribution does not pass the significance test. In addition, I assess the contribution of each component of the grammar: markedness, faithfulness, and JTOE.

Likelihood ratio tests on individual constraints reveal that the effects of NOLAPSE, INITFT, WSP, WSP(G), WSP(N), and DEP[ACC](PS) are not statistically significant. This suggests that the foot structures targeted by NOLAPSE and INITFT (i.e., successive unparsed syllables and word-initial unparsed syllables) are not notably worse than other unparsed syllables penalized by PARSE-σ. This is not surprising given the unaccented pattern remains underpredicted even in the final model: the primary function of these two constraints is to exhaustively parse syllables, which is necessary for producing unaccented words (i.e., ^{0}[(H)(LL)], ^{0}[(LL)(LL)]). The insignificance of WSP, WSP(G), and WSP(N) suggests that the widely recognized tendency of heavy syllables to attract stress is primarily due to heavy syllables with long vowels or diphthongs (i.e., WSP(V)). Additionally, the role of DEP[ACC](PS) is largely subsumed by FAITH-JTOE[ACC], but DEP[ACC] remains significant, indicating faithfulness to both primary and secondary stress in source words.

Column (e) in Table 5 showcases the best-fit constraint weights in the final model. The log likelihood of the final model was **-1984.08**, a drop of 1.80 from the larger model discussed in the previous section.

To assess the impact of each component in the model, each component was removed from the final model, and the changes in log likelihoods (Δ log likelihoods) were compared. Note that WDACC is considered a markedness constraint, although it can also be viewed as a faithfulness constraint (i.e., MAX[ACCENT]). The results, summarized in Table 11, show that the markedness effects have the largest contribution (Δ log likelihood = 1757.16). This is followed by the faithfulness effects to source words (Δ log likelihood = 122.57), and the faithfulness effects to the JTOE have the least impact (Δ log likelihood = 31.37).

Included component	Excluded component	Log likelihood	Δ log likelihood
Faithfulness & JTOE	Markedness	-3741.24	1757.16
Markedness & JTOE	Faithfulness	-2106.66	122.57
Markedness & Faithfulness	JTOE	-2015.45	31.37

Table 11. Contribution of each component of the grammar.

4.5. Summary

The MaxEnt modeling described in this section demonstrates the significant contribution of faithfulness effects to English source words and Japanese speakers' implicit knowledge of the English stress system (along with additional markedness effects).

The faithfulness model confirmed the significance of two faithfulness effects: loanword syllables from stressed syllables in English source words, whether primary or secondary, tend to be accented (i.e., DEP[ACC]), and epenthetic syllables, derived from consonant clusters in English, tend to avoid accents (i.e., DEP[V́]). This improvement in the model's fit to the data (Δ log likelihood = 122.57 from the final model in Section 4.4.5) suggests that loanwords with faithfulness-driven accents represent a probabilistic interplay between markedness and faithfulness, rather than being idiosyncratic exceptions. However, the impact of faithfulness effects is substantially smaller than that of markedness effects (1757.16 vs. 122.57), highlighting the secondary nature of faithfulness in the overall model.

The JTOE model confirmed the crucial role played by Japanese speakers' implicit knowledge of the English stress system, particularly in assigning (pre-)pre-antepenultimate-mora accent when the stress patterns of the source words and markedness principles favor other accent patterns. In this case, faithfulness to the JTOE takes precedence over faithfulness to the actual input and markedness effects, resulting in hyperforeignization. To my knowledge, this model represents the first attempt to incorporate a module that reflects borrowers' theory of a source language into a model of loanword adaptation.

Finally, the final model presented in this section encounters certain limitations, notably its underprediction of the unaccented pattern. A possible hypothesis is that loanwords with typically unaccented syllable structures (i.e., [HLL], [LLLL] ending in a full vowel) might frequently be orthographic borrowings, devoid of faithfulness to the stress patterns of their source words. This might also lead to Japanese speakers' uncertainty about the general stress patterns of source words with such structures, reducing the impact of the JTOE effect as well. A deeper investigation into this issue would require differentiating between auditory and orthographic borrowings and refining the JTOE.

5. Discussion

This study has demonstrated that employing a probabilistic approach leads to a more accurate and comprehensive model of loanword accentuation in Japanese. This section discusses implications of these findings and some remaining issues for future research.

5.1. Pre-antepenultimate-mora accent

As noted in Section 2.2, Katayama (1998) and Kubozono (2006) identified the existence of pre-antepenultimate-mora accent in loanwords ending with LH. While Kubozono attributed this pattern to a shift towards a Latin Stress-like rule in phonological grammar, the reasons behind this shift were not explicitly discussed. This study suggests that the emergence of this accent pattern is mainly driven by faithfulness to source words and the JTOE. Moreover, it reveals that the occurrence of pre-antepenultimate-mora accent (and even pre-pre-antepenultimate-mora accent) is more common than previously recognized, appearing in numerous longer loanwords ending in HL or LLL.

Determining the exact contribution of faithfulness and markedness effects to this accent pattern is challenging and likely varies among individuals. Some might argue that accent patterns initially induced by faithfulness are later reanalyzed as stemming from markedness in synchronic grammar (cf. C. Ito 2014 on loanword accentuation in Yanbiam Korean). However, the identification of faithfulness effects alongside the comprehensive markedness effects based on Ito and Mester's (2016) model indicates the significance of faithfulness in assigning (pre-)pre-antepenultimate-mora accent, even in synchronic grammar. In other words, this accent pattern cannot be solely attributed to markedness effects. An experimental study is needed to delve further into the contribution of each factor.

5.2. Where does loanword accentuation come from?

The literature disagrees on the origin of loanword accentuation in Japanese. Mutsukawa (2005, 2006) considers faithfulness to source words to be the dominant factor in Japanese loanword accentuation. Kubozono (2006), on the other hand, argues that while the tendency of English loanwords to be accented comes from Japanese speakers' knowledge that English words are pronounced with a pitch fall in isolation, the location of the accent is determined by the native phonological grammar. However, this study indicates that both perspectives may not fully capture the reality: the accent's location is clearly influenced by faithfulness, but it is not the dominant factor.

In the context of loanword accentuation in Yanbian Korean, C. Ito (2014) proposes a mechanism of loanword adaptation concerning pitch accent. C. Ito suggests that at the initial stage of the borrowing all loanwords are adapted as faithfully as possible to the source words, introducing only faithfulness constraints. After a certain number of loanwords are borrowed, speakers start to analyze the accentuation in loanwords phonologically and assign weights to markedness constraints, reducing the weights of faithfulness constraints. In the context of loanword accentuation in Japanese, C. Ito's model would predict an accent system that closely resembles the English stress system, similar to the JTOE component in this study. However, as detailed in Section 4.4.5, the JTOE's influence in the current analysis is not dominant; instead, there are substantial markedness effects, generally favoring antepenultimate-mora accent. Additionally, the presence of the unaccented pattern highlights the importance of markedness effects, as it cannot be accounted for by faithfulness.

Overall, this study proposes that Japanese loanword accentuation is shaped by a stochastic interplay of three factors: Japanese-internal markedness principles, faithfulness to source words, and faithfulness to Japanese speakers' theory of the English stress system. Future studies may delve into understanding how Japanese children acquire and internalize the system of loanword accentuation.

This conclusion draws attention to the question of the source of markedness effects. In this study, Ito and Mester's (2016) markedness system was employed as a baseline, under the assumption that it reflects the most frequent accent patterns in native and Sino-Japanese words, as suggested by Kubozono (2006). However, this assumption requires verification, and the mechanism behind such preference for dominant patterns needs to be explored in future research.

5.3. Japanese Theory of English

Given that borrowing foreign words necessarily involves language contact, it is not surprising that borrowers develop a theory of the source language during this process. In the context of loanword accentuation in Japanese, speakers develop a theory of the English stress system that predicts the stress location in English source words based on syllable structure.

Smith (2009) attributes the phenomenon of loan doublets, where a single word is borrowed twice and yields different forms, to two distinct borrowing channels: auditory and orthographic. To account for both scenarios, Smith suggests that the input representations to which borrowers aim to be faithful are not always consistent. Instead, they can differ depending on the context of language contact. Smith refers to these as "posited representations", which are shaped by a range of factors, including perceptual and orthographic information, as well as explicit knowledge of the source language. In a sense, the JTOE can be understood as an extension of Smith's (2009) model. Echoing Kang et al.'s (2014) study on the adaptation of French loanwords in Vietnamese, this study identified the significant role that borrowers' implicit knowledge of the source language plays in loanword adaptation. Moreover, it suggests a method to quantitatively incorporate this influence into an explicit model.

There remain several questions regarding the JTOE that need to be addressed in future studies. I will outline three of these questions below. First, given the complexity of the English stress system, it seems reasonable to assume that the JTOE is less detailed than the descriptively optimum model. Indeed, Kang et al. (2014) also note that the knowledge of the source language phonotactics is "not native-like" in the context of French loanwords in Vietnamese. However, the specific aspects in which the JTOE is less detailed remain an empirical question that requires experimental investigation. Additionally, it is expected that different speakers may possess different versions of the JTOE, influenced by factors like the level of proficiency in English. It would be valuable to explore how the quality of JTOE varies based on the extent of English knowledge among Japanese speakers and how in turn it affects their adaptations.

Second, while this study incorporated JTOE effects as a factor influencing both auditory and orthographic adaptations, this assumption needs to be tested through experimental research. It is plausible to expect a more pronounced JTOE influence in instances where loanwords are borrowed solely based on orthographic information, or where the source pronunciation is not readily accessible. In such scenarios, one of the competing factors, namely faithfulness to the stress patterns of the actual source words, is absent given that English orthography does not spell stress. However, the question arises: does the JTOE still play a role when the source pronunciation is available? Essentially, is there a competition between these two types of faithfulness in online adaptation? While delving into this question exceeds the scope of the current study, exploring it is crucial to fully comprehend the structure of the representations to which borrowers strive to remain faithful.

Finally, it would be crucial to understand the specific circumstances under which the JTOE influences loanword accentuation. Questions arise such as: Does the JTOE affect the accent of loanwords borrowed from languages other than English? How does it function when borrowers are unaware of a loanword's origin? Is the similarity of phonotactic patterns to English words a factor? Moreover, do social factors like conversation topic or the identity of the interlocutor play a role? These aspects present valuable avenues for future experimental research to explore.

Appendix: Summary of the corpus data

The tables below display the accent patterns for syllable structures: Pre2 = pre-pre-antepenultimate-mora, Pre = pre-antepenultimate-mora, Ant = antepenultimate-mora, Pen = penultimate-mora, Ult = ultimate-mora, Un = unaccented (Pre3 = pre-pre-pre-antepenultimate-mora). Their organization reflects the categorization outlined in Section 3.2.

a. Loanwords with two or three moras

	Pre2	Pre	Ant	Pen	Ult	Un	Sum
H				40		0	40
LL				111	0	3	114
LH			129	26		11	166
HL			339		0	58	457
LLL			257	17		35	310

b. Loanwords ending in HH or HLL

	Pre2	Pre	Ant	Pen	Ult	Un	Sum
HH			174	6		18	198
LHH	0		30	0		6	36
HHH	0		14	0		0	14
LLHH	0 (Pre3: 0)		28	0		1	29
LHHH	0 (Pre4: 0)		3	0		0	3
HLHH	0 (Pre3: 0)		9	0		0	9
HLL			122	1	0	61	184
LHLL	0		30	0	0	2	32
HHLL	0		9	1	0	0	10

c. Loanwords ending in HL or LLL

	Pre2	Pre	Ant	Pen	Ult	Un	Sum
LHL		63	73		0	63	419
HHL		44	33		0	0	77
LLHL	43	10	143		0	3	199
HLHL	39	2	39		0	0	61
LHHL	(Pre3: 0)	8	12		0	0	20
HHHL	(Pre3: 0)	0	5		0	0	5
LLLL		66	36	1	0	90	193
HLLL		19	21	2	0	4	46

d. Loanwords ending in LH

	Pre2	Pre	Ant	Pen	Ult	Un	Sum
LLH		132	26	2		33	193
HLH		52	16	0		7	75
LLLH	16	48	16	0		5	85
HLLH	16	48	16	0		1	25
LHLH	0 (Pre3)	11	3	0		0	14
HHLH	0 (Pre3)	2	1	0		0	3

References

Allen, W. S. (1973). *Accent and rhythm*. Cambridge University Press, Cambridge.

Beckman, M. E. (1986). *Stress and Non-Stress Accents*. Dordrecht, the Netherlands: Foris Publications.

Beckman, M. E., & Pierrehumbert, J. B. (1986). Intonational structure in Japanese and English. *Phonology*, *3*, 255-309.

Boersma, P., & Hamann, S. (2009). Loanword adaptation as first-language phonological perception. In A. Calabrese, & L. Wetzels (Eds.), *Loan phonology* (pp. 11-58). Amsterdam: John Benjamins.

Brysbaert, M., & New, B. (2009). Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior research methods*, *41*(4), 977-990.

Chomsky, N., & Halle, M. (1968). *The sound pattern of English*. New York: Harper and Row.

Daland, R., Oh, M., & Kim, S. (2015). When in doubt, read the instructions: Orthographic effects in loanword adaptation. *Lingua*, *159*, 70-92.

Davis, S., Tsujimura, N., & Tu, J. Y. (2012). Toward a taxonomy of loanword prosody. *Catalan Journal of Linguistics*, *11*, 13-39.

Féry, C. (2003). Markedness, faithfulness, vowel quality and syllable structure in French. *Journal of French Language Studies*, *13*(2), 247-280.

Fylstra, D., Lasdon, L., Watson, J., & Waren, A. (1998). Design and use of the Microsoft Excel Solver. *Interfaces 28*(5). 29-55.

Goldwater, S., & Johnson, M. (2003). Learning OT constraint rankings using a maximum entropy model. In J. Spenader, A. Eriksson, & O. Dahl (Eds.), *Proceedings of the Stockholm workshop on variation within optimality theory* (pp. 111-120). Stockholm: Stockholm University.

Gordon, M. (2002). A phonetically driven account of syllable weight. *Language*, 51-80.

Gordon, M. (2007). *Syllable weight: phonetics, phonology, typology*. Routledge.

Glewwe, E. (2021). The phonological determinants of tone in English loanwords in Mandarin. *Phonology*, *38*(2), 203-239.

Hamann, S., & Colombo, I. E. (2017). A formal account of the interaction of orthography and perception: English intervocalic consonants borrowed into Italian. *Natural Language & Linguistic Theory*, *35*, 683-714.

Haraguchi, S. (1991). *A Theory of Stress and Accent*. Dordrecht: Foris.

Hayes, B. (1982). Extrametricality and English stress. *Linguistic inquiry*, *13*(2), 227-276.

Hayes, B. (2011). English Phonology Search [Computer software]. Retrieved from https://linguistics.ucla.edu/people/hayes/EnglishPhonologySearch/Index.htm

Hayes, B., & Wilson, C. (2008). A maximum entropy model of phonotactics and phonotactic learning. *Linguistic inquiry*, *39*(3), 379-440.

Ito, C. (2014). Loanword accentuation in Yanbian Korean: a weighted-constraints analysis. *Natural language & linguistic theory*, *32*, 537-592.

Ito, J., & Mester, A. (2016). Unaccentedness in Japanese. *Linguistic Inquiry*, *47*(3), 471-526.

Jarosz, G. (2015). *Expectation driven learning of phonology*. Unpublished manuscript.

Janda, R. D., Joseph, B. D., & Jacobs, N. G. (1994). Systematic Hyperforeignisms as Maximally External Evidence for Linguistic Rules. In S. Lima, R. Corrigan, & G. Iverson (Eds.), *The Reality of Linguistic Rules* (pp. 67-92). Amsterdam: John Benjamins Publishing.

Kang, Y. (2003). Perceptual similarity in loanword adaptation: English postvocalic word-final stops in Korean. *Phonology* 20. 219-273.

Kang, Y. (2010). Tutorial overview: Suprasegmental adaptation in loanwords. *Lingua*, *120*(9), 2295-2310.

Kang, Y., Phạm, A. H., & Storme, B. (2014). French loanwords in Vietnamese: the role of input language phonotactics and contrast in loanword adaptation. In *Proceedings of the Annual Meetings on Phonology* (Vol. 2).

Katayama, M. (1998). *Optimality Theory and Japanese loanword phonology* [Doctoral Dissertation, University of California, Santa Cruz].

Kenstowicz, M., & Sohn, H. S. (2001). Accentual adaptation in north kyungsang Korean. *Current Studies in Linguistics Series*, *36*, 239-270.

Kenstowicz, M., & Suchato, A. (2006). Issues in loanword adaptation: A case study from Thai. *Lingua*, *116*(7), 921-949.

Kenstowicz, M. (2007). Salience and similarity in loanword adaptation: a case study from Fijian. *Language Sciences*, *29*(2-3), 316-340.

Kilbourn-Ceron, O., & Sonderegger, M. (2018). Boundary phenomena and variability in Japanese high vowel devoicing. *Natural Language & Linguistic Theory*, *36*, 175-217.

Kubozono, H. (1993). *The Organization of Japanese Prosody,* Tokyo: Kuroshio Publishers.

Kubozono, H. (2006). Where does loanword prosody come from?: A case study of Japanese loanword accent. *Lingua*, *116*(7), 1140-1170.

Kubozono, H. (2015). Loanword phonology. In H. Kubozono (Ed.), *Handbook of Japanese phonetics and phonology* (pp. 313-361). Walter de Gruyter GmbH & Co KG.

Laver, J. (1994). *Principles of phonetics*. Cambridge: Cambridge University Press.

Lee, D. (2009). *The loanword tonology of South Kyungsang Korean* (Doctoral dissertation, Indiana University).

Lieberman, P. (1960). Some acoustic correlates of word stress in American English. *Journal of the Acoustical Society of America, 32*(4), 451-454.

Liberman, M., & Prince, A. (1977). On stress and linguistic rhythm. *Linguistic inquiry*, *8*(2), 249-336.

McCawley, J. D. (1968). *The Phonological Component of a Grammar of Japanese*. The Hague: Mouton.

McCawley, J. D. (1977). Accent in Japanese. *Studies in stress and accent*, *4*, 261-302.

Moore-Cantwell, C. (2020). Weight and final vowels in the English stress system. *Phonology*, *37*(4), 657-695.

Mutsukawa, M. (2005). Loanword accentuation in Japanese. *University of Pennsylvania Working Papers in Linguistics*, *11*(1), 199-212. Pennsylvania: Penn Linguistics Club.

Mutsukawa, M. (2006). *Japanese loanword phonology in Optimality Theory: The nature of inputs and the loanword sublexicon* [Doctoral dissertation Michigan State University].

NHK Hōsō Bunka Kenkyūjo, (Ed.) (2016). *NHK Nihongo hatsuon akusento shin-jiten [NHK Pronunciation and Accent Dictionary].* Tokyo: NHK Shuppan.

Oh, Y., Todd, S., Beckner, C., Hay, J., King, J., & Needle, J. (2020). Non-Māori-speaking New Zealanders have a Māori proto-lexicon. *Scientific reports*, *10*(1), 1-9.

Panther, F. A., Mattingley, W., Todd, S., Hay, J., King, J., & Panther, F. (2023). Proto-lexicon size and phonotactic knowledge are linked in non-Māori speaking New Zealand adults. *Laboratory Phonology*, *14*(1).

Pater, J. (2000). Non-uniformity in English secondary stress: the role of ranked and lexically specific constraints. *Phonology*, *17*(2), 237-274.

Peperkamp, S., Vendelin, I., & Nakamura, K. (2008). On the perceptual origin of loanword adaptations: Experimental evidence from Japanese. *Phonology, 25*, 129-164.

Prince, A., & Smolensky, P. (2004). Optimality Theory: Constraint interaction in generative grammar. *Optimality Theory in phonology: A reader*, 1-71.

Ryan, K. M. (2011). Gradient syllable weight and weight universals in quantitative metrics. *Phonology*, *28*(3), 413-454.

Selkirk, E. O. (1984). Phonology and syntax: the relation between sound and structure. Cambridge, MA: MIT Press.

Shinohara, S. (2000). Default accentuation and foot structure in Japanese: Evidence from Japanese adaptations of French words. *Journal of East Asian Linguistics*, *9*(1), 55-96.

Shinohara, S. (2004). Emergence of universal grammar in foreign word adaptations. *Constraints in phonological acquisition*, 292-320.

Shoji, S., & Shoji, K. (2014). Vowel epenthesis and consonant deletion in Japanese loanwords from English. *Proceedings of the Annual Meetings on Phonology,* 1(1).

Silverman, D. (1992). Multiple scansions in loanword phonology: Evidence from Cantonese. *Phonology*, *9*(2), 289-328.

Smith, J. L. (2009). Source similarity in loanword adaptation: Correspondence theory and the posited source-language representation. In S. Parker (Ed.), *Phonological argumentation: Essays on evidence and motivation* (pp. 155-77). London: Equinox.

Storme, B. (2017). The loi de position and the acoustics of French mid vowels. *Glossa: a journal of general linguistics*, *2*(1), 1-25.

Tesar, B., & Smolensky, P. (1998). Learnability in optimality theory. *Linguistic Inquiry*, *29*(2), 229-268.

Tsuchida, A. (1997). *Phonetics and phonology of Japanese vowel devoicing* [Doctoral dissertation, Cornell University].

Tsuchida, A. (2001). Japanese vowel devoicing: Cases of consecutive devoicing environments. *Journal of East Asian Linguistics*, *10*(3), 225-245.

Venditti, J. J. (1997). Japanese ToBI labelling guidelines. *Working Papers in Linguistics-Ohio State University Department Of Linguistics*, 127-162.

Wasserman, L. (2004). *All of statistics: A concise course in statistical inference*. New York: Springer.

Weide, R. L. (1994). CMU pronouncing dictionary. http://www.speech.cs.cmu.edu/cgi-bin/cmudict.

Yip, M. (2006). The symbiosis between perception and grammar in loanword phonology. *Lingua*, *116*(7), 950-975.

Zuraw, K., O'Flynn, K. C., & Ward, K. (2019). Non-native contrasts in Tongan loans. *Phonology*, *36*(1), 127-170.