Hiatus-Conditioned Accent Shift in Japanese:
Expanding the Vowel Sonority Hierarchy

Blake Allen
University of British Columbia

1 Introduction

Among the less studied phonological patterns in Standard Tokyo Japanese is a type of accent "shift" conditioned by vowel hiatus in verbs. The lexical items exhibiting this pattern possess an accent (a sharp pitch fall) one mora away from the penultimate position typical of verbal accent. Moreover, many lexical items exhibit phonologically principled variability in their susceptibility to accent shift. In this paper, I propose that this phenomenon—and especially the observed patterns of variability—can be accounted for using a modified version of de Lacy's (2004) theory of *markedness conflation*, in which a stringency hierarchy of vowel sonority levels is encoded as a set of markedness constraints targeting nested subsets of the vowel inventory. After presenting previously undescribed lexical statistics related to accent shift, I argue that the following modifications to de Lacy's theory are warranted: 1) that the sonority scale be expanded to include distinctions between front/back or unrounded/rounded vowels (*contra* Kenstowicz 1997), and 2) that instead of strictly ranked constraints, this hierarchy must be expressed as weighted constraints (Legendre et al. 1990; Hayes and Wilson 2008) in order to allow gang-up effects (Farris-Trimble 2008; Jesney and Tessier 2009).

In addition to demonstrating the explanatory adequacy of this proposal, I provide experimental evidence that native speakers of Japanese have knowledge of accent patterns compatible with such a stringency-based analysis. To this end, I present the results of a nonce-word experiment designed to collect judgments about acceptable accent positions in novel items similar to native Japanese (Yamato) verbs. The results of this experiment indicate that subjects do use a sonority-based generalization compatible with the stringency-theoretic analysis proposed here in their evaluation of acceptable accent locations, and that knowledge of the phonotactic patterns on Sino-Japanese morphemes also plays a large role.

Section 2 introduces the phenomenon of hiatus-triggered accent shift and other relevant phonotactic patterns in the Japanese lexicon. Section 3 then presents the sonority-based analysis of the verbal patterns. Section 4 explains the methodology of a experiment designed to elicit Japanese speakers' generalizations about this pattern, and Section 4 describes its results. Section 5 concludes with a summary and discussion of the broader implications of my findings.

2 Accent in Vowel Hiatus Environments

Hiatus-conditioned accent shift in Japanese verbs is a comparatively under-studied phenomenon. This section presents the basic facts of these patterns, as discussed in Haraguchi (1996), as well as the results of my own examination of accent shift patterns across a comprehensive corpus of native (Yamato) Japanese verbs. I also give a summary of accent patterns in vowel hiatus environments among Sino-Japanese morphemes, which are important in interpreting the experimental results.

2.1 Japanese Accent "Shift"

In Standard Tokyo Japanese, verbs and verbal ("-i") adjectives are typically considered to fall into two accentual classes: those with accent, which is (almost) always on the penultimate mora or vowel, and those with no accent (McCawley 1965; Haraguchi 1996). Accent is indicated by a sharp drop in F_0 (Beck-

man and Pierrehumbert 1986). Class membership is not phonologically or semantically predictable, as the overview in (1) sketches. Note that Japanese forms in this paper are provided in phonemic transcriptions, and accent is marked as V́.

(1)

accented verbs		*unaccented verbs*	
bakéru	'to be disguised'	sitoru	'to be soaked'
habámu	'to prevent'	susumu	'to proceed'
simésu	'to show'	tobasu	'to fly (trans.)'

Among the accented verbs and verbal adjectives, accent is typically on the penultimate vowel, as in (1). In a small number of verbs, however, accent falls instead on the antepenultimate vowel:

(2)

no shift		*shift*	
hiéru	'to grow cold'	háiru	'to enter'
koéru	'to become fat'	máiru	'to go (hum.)'
taósu	'to defeat'	káeru	'to return (intrans.)'
kuíru	'to regret'	hirugáesu	'to turn over (trans.)'
Total: hundreds		*Total: 10*	

This phenomenon has been called *accent shift*—parallel to the better known "shift" of accent away from devoiced vowels—by Haraguchi (1996), who to my knowledge is the only other linguist to have documented it. The question of whether a moraically penultimate accent actually shifts leftward during the derivation of these verbs or, instead, there are simply three verbal prosodic classes instead of two will not be a relevant distinction for this paper, and so for purposes of terminological consistency and brevity I will refer to verbs with moraically antepenultimate accent as *accent shift verbs*, and to moraically antepenultimate accent itself as *accent shift*.

All accent shift verbs lack a consonant between the antepenultimate and penultimate vowels, but not all verbs with this -VV(C)V shape exhibit accent shift. Moreover, according to the Japanese Pronunciation and Accent Dictionary (NHK 1985) and Haraguchi (1996), many verbs are variable in their accent shift status. (3) provides a non-exhaustive list of words in this category. All such variably-shifting words have either the vowel sequence [ae] or [oe] in the relevant position; note however that many verbs with these vowel sequences never exhibit accent shift, and almost none exhibit categorical accent shift; exceptions will be discussed presently.

(3)

variable shift			
osáeru	*or*	osaéru	'to seize'
otoróeru	*or*	otoroéru	'to weaken'
kotáeru	*or*	kotaéru	'to answer'
norikóeru	*or*	norikoéru	'to climb over'
		Total: 24	

The identity of the penultimate and antepenultimate vowels is the only type of phonological information I have found to correlate with the occurrence of accent shift. Based on the Japanese Pronunciation and Accent Dictionary (NHK 1985) and PSYLEX (Amano and Kondo 1999), I have compiled detailed information about accent patterns on shift-eligible verbs across the all shift-eligible verbs in the native (Yamato) stratum. (5) outlines the observed patterns of shift, non-shift, and variability for each possible vowel-vowel combination, based on the key in (4).

(4) For each antepenultimate-penultimate VV sequence:
s = there exist verbs with this sequence which exhibit *categorical* accent shift

v = there exist verbs with this sequence which exhibit *variable* accent shift
n = there exist verbs with this sequence which *never* exhibit accent shift
a blank cell indicates that no verbs with this sequence exist

(5)

V1\V2	a	i	u	e	o
a		s		(s)vn	n
i		n		n	n
u		n		n	n
e				n	
o		n		vn	n

As indicated by the *(s)* mark in (5), the number of words with an [ae] sequence which are invariably shifted is limited: they include only *káeru* 'to return (intrans.)', *káesu* 'to return (trans.)', and several of their derivative complex verbs, such as *wakagáeru* 'to be rejuvenated' and *hirugáeru* 'to turn over, flutter'. Some derivatives of these words, however, have variable accent shift, e.g. *kutsugáesu/kutsugaésu* 'to overturn' and *kurikáesu/kurikaésu* 'to repeat'[1]. Excepting these special [ae] verbs, then, the chart in (5) can be summarized as demonstrating that: 1) [ai] is always shifted, 2) [ae] and [oe] are either variably or never shifted, and 3) other attested sequences are never shifted.

Non-shifted verbs are more common than variably shifted ones among those with [ae] and [oe] sequences. There are only twenty-four words with variable accent shift: twenty-one with [ae] and three with [oe]. Out of the 15,818 verbs listed in PSYLEX, non-shifted [ae] verbs total to approximately five hundred, and non-shifted [oe] verbs to 108. Words in each category (variably- or non-shifting) range from very high to very low token frequency.

Crucially for the research described here, however, there is a complete lack of information available to Japanese speakers about accent shift on nearly half of the twenty-five possible vowel-vowel combinations; refer back to the empty cells in (5). The origins of these gaps vary. Some, such as the lack of [eV] sequences other than [ee], can be attributed to historical change (Frellesvig 2010). Here I only consider simplex verbs, since verbal compounding can sometimes produce penultimate vowel-vowel sequences, e.g. *deru* 'to leave' + *au* 'to meet' yields *deau* 'to happen to meet'. However, accent shift never occurs across morpheme boundaries, and these compounds often have distinctive accent patterns (Ito and Mester 2007).

Note too that verbs derived from Chinese and assimilated into the Japanese verb system by addition of final *-ru*, *-su*, *-zu*, or *-suru* are also not included here. The subset of these "hybrid" words with adjacent vowels in the penultimate and antepenultimate positions categorically exhibit accent shift, as in *tóoru* 'to go through' and *táisu* 'to oppose'. However, because this shift is actually a universal trait of Sino-Japanese syllables—which never host accent on their second mora—one could argue that these words are uninformative about accent patterns on native Japanese (Yamato) words. As the results of the experiment will demonstrate, however, this distinction cannot be taken for granted: perhaps due to just these such words, Sino-Japanese accent phonotactics cannot be completely disentangled from the accent patterns of words in the Yamato stratum.

2.2 Sino-Japanese Accent Patterns

Because accent patterns within the Sino-Japanese stratum will prove relevant when discussing the results of my experiment, I provide a brief description of them here. Accent within a Sino-Japanese morpheme will always be on its first mora (McCawley 1965). For the present purposes, the Sino-Japanese

[1] Some derivatives of the 'return' words have morphological constituency that is orthographically opaque while others are orthographically transparent, but this distinction correlate with a complex verb's tendency toward or away from invariable accent shift. By orthographically transparent, I mean that one of the *kanji* (Chinese characters) with the meaning of *kaeru* is present in the compound.

morphemes of interest are those with sequences of two vowels in hiatus. The possible shapes of these morphemes derive from the ways that morphemes were borrowed from Chinese languages, as well as the sound changes that occurred to those morphemes; whereas each morpheme in Chinese languages is monosyllabic, their Japanese equivalents are maximally bimoraic (Frellesvig 2010). Such sequences found in Japanese are listed below:

(6)

[ai]	*ai* 'love'
[uu]	*kuu* 'emptiness'
[ui]	*sui* 'water'
[ei/ee]	*mei*/*mee* 'name'
[ou/oo]	*tou*/*too* 'tower'

The sequences [ei/ee] and [ou/oo] are problematic. Whether or not [ei] and [ou] even exist morpheme-internally is a matter of considerable doubt, and at the very least these two pairs of sequences are phonetically identical in such contexts (Kawakami 2001; Hirayama 2003). Members of each pair are only distinguished by their different orthographical representations (Okada 1991), which depend on lexical stratum and morphological constituency. The phonetic realizations of these sequences are [ee] and [oo], but whereas they are typically written as [ee] and [oo] in Yamato words, they are written as [ei] and [ou] in Sino-Japanese words, recent loanwords, and a small number of Yamato words. With the exception of loan words, this peculiar orthographical convention is due to historical change (Frellesvig 2010). Even so, because [ei] and [ou] are logically possible vowel combinations in the Japanese phonological system, I include these sequences in my investigation of accent shift.

3 The Sonority-Based Analysis

In this section I present an analysis of Yamato verb accent shift patterns which relies on an extension of de Lacy's (2004) theory of markedness conflation, specifically of vowel sonority levels. Subsection 1 sets up the desired features of such an analysis, and subsection 2 gives the specifics of a constraint-based implementation.

3.1 The Generalization

Research on the role of relative vowel sonority tends toward a sonority scale like that in (7) for a typical five vowel system (Kenstowicz 1997; de Lacy 2004).

(7) a > o,e > u,i

The observed vowel sequences in Japanese verbs which exhibit accent shift are, in descending order of accent shift probability, [ai], [ae], and [oe]. Consider the possibility that, just as in the sonority-based stress systems described in Kenstowicz (1997), these patterns can also be described as a tendency for accent to "shift" away from less sonorous vowels and onto more sonorous vowels. The scale in (7) would partition the vowel space as in (8), which is a version of (5) reordered and divided in accordance with this sonority scale.

(8)

$V1 \backslash V2$	a	o	e	u	i
a		n	(s)vn		s
o		n	vn		n
e			n		
u		n	n		n
i		n	n		n

The divisions in (8) do not accurately predict the observed correlations between vowel sequence and accent shift: the difference for V_2 between [ae] and [oe] on one hand and [ao] and [oo] on the other exhibits a distinction that is lost by the lack of a partition in this sonority hierarchy between [o] and [e]. Additionally, for V_1, there is a distinction in shift probability between [oe] and [ee]/[ue]/[ie] that is similarly lost. Even if some part of these patterns is attributed to a dispreference for accent shift of sequences of identical vowels (despite a tendency toward just such a shift elsewhere in the language, as described previously), the distinction between [ae] and [ao] at least is evidence for some difference in sonority between [o] and [e].

Despite claims by de Lacy (2006) that neither the roundedness nor the backness of a vowel affects its sonority level, there have been descriptions of phonological processes in at least two languages which indicate phonological sensitivity to just such distinctions. Matthews (1991) gives an analysis of vowel deletion in inter-morphemic vowel hiatus environments in Modern Greek by which the less sonorous vowel deletes. Because of forms like /to + eleɣa/ → [toleɣa] 'I was saying,' he concludes that [o] dominates [e] in terms of sonority. Selection of which vowel deletes cannot merely be positional: compare /ta + evlepa/ → [tavlepa] 'I saw them' and /to + alo/ → [talo] 'the other.' Pulleyblank (2008) adduces from similar patterns in Yoruba evidence for a sonority-based distinction between the high vowels [u] and [i][2]. Phonetic evidence for a difference in sonority between front and back vowels has also been described by Pike (1972) and Foley (1977).

Based on these observations, I propose a more finely articulated hierarchy of vowel sonority than that used by Kenstowicz (1997) or de Lacy (2007):

(9) a > o > e > u > i

Assuming such a scale, it is now possible to describe the apparent difference in accent shift probability between [o] and [e] in both V_1 and V_2 positions. Indeed, I propose that exists some *especially salient* "boundary" in Japanese between [o] and [e] on this scale.

(10) a > o >>> e > u > i

The generalization about accent shift patterns based on this revised scale is as follows: sequences crossing the "o > e" boundary rightward—i.e., sequences with decreasing sonority in which V_1 is to the left of the boundary and V_2 is to the right—are able to exhibit accent shift. This "conflation" of sonority levels on either side of the o > e boundary parallels the proposal in de Lacy (2007), which will be addressed in the following subsection.

The most attractive feature of this analysis, however, is its ability to explain the specific patterns of variability among accent shift verbs. Among vowel sequences crossing this boundary which are attested in Japanese verbs, [ai] is always shifted, [ae] is categorically shifted for some words and always shifted for others, and [oe] is only variably shifted. (Some [ae] and [oe] words also never exhibit shift.) These three levels of "shiftability" correspond directly to the distances of each vowel sequence's members from each other on the scale, as illustrated in (11).

(11)

————————————————>	[ai] (high shiftability)
————————————>	[ae] (medium shiftability)
——————>	[oe] (low shiftability)
————>	[ao] (non-shifting)
a > o >>> e > u > i	

There is exactly one word which fails to exhibit accent shift despite being predicted to do so by

[2]This distinction may also correspond to the difference in markedness between diphthongal *ai* and *au* that Kubozono (2001) describes in Japanese and English.

this analysis: *oíru* 'to be old'. Note though that this word is of quite low frequency in spoken Japanese, with the word *toshitóru* 'to grow old' typically used instead, and that there also exists a medium frequency word *óiru* 'oil' with initial accent but otherwise identical to it. Creating a generalization that does not account for this one form may also be justified by evidence that observation of a single unpredicted form does not drastically change learners' understanding of broader phonological patterns, as in the non-generalization of the *ox* ~ *oxen* paradigm to novel words in English (Becker et al. 2012).

3.2 The Constraint-Based Implementation

In order to understand how to express this generalization in a constraint-based framework, let us first consider a hypothetical version of this pattern which is purely categorical: accent is antepenultimate in all vowel sequences in which V1 is to the "left" of the o/e divide and V2 is to its "right," and penultimate in all other sequences:

(12) *Antepenultimate accent*:
[ae], [au], [ai], [oe], [ou], [oi]
Penultimate accent:
(all others)

This pattern constitutes a case of *markedness conflation* as described by de Lacy (2004). Rather than accent position in this hypothetical version of Japanese being sensitive to all distinctions along the (universal) vowel sonority hierarchy as proposed by Prince and Smolensky (2008), the grammar ignores certain possible contrasts along that scale, such as [e] > [i], in effect "conflating" these levels. Describing this pseudo-Japanese pattern is straightforward using only the machinery proposed by de Lacy (2004), with the exception of an additional layer of distinctions between front and back vowels of the same height ([o] > [e], and [u] > [i]). The constraints relevant to this pattern are given in (13), and do not need to be ranked relative to each other to produce this desired pattern, as shown in (14). An alternative ranking, in which *ACCENT/i,u,e dominates *ÝV and *UNACCENTED/a,o is omitted, can also produce these patterns; however, *UNACCENTED constraints will be necessary to account for the actual observed Japanese data, and so are included here for illustrative purposes. Note that a separate constraint, not listed here, ensures that exactly one accent appears on this sequence.

(13) *ACCENT/i,u,e , *UNACCENTED/a,o , *ÝV

(14)

	*ACCENT/i,u,e	*UNACCENTED/a,o	*ÝV
→ái			*
aí	*!	*	
→áe			*
aé	*!	*	
áa		*	*!
→aá		*	
áo		*	*!
→aó		*	
íi	*		*!
→ií	*		
ía	*!	*	*
→iá			*

Although able to predict the stipulated patterns of this particular type of pseudo-Japanese, this

constraint ranking is unable to generate the degree of variability observed in the real Japanese verbal paradigm, i.e. more accent shift on [ai], less on [ae], still less on [oe], and none on other sequences. In order to account for this gradience, further constraints must be included in the calculation of output probabilities. Conveniently, de Lacy's (2004) theory of markedness conflation and "stringency" constraints provides a useful set of constraints for this purpose, namely the members of the stringency hierarchy not given above. The subset of this hierarchy of constraints which govern accent placement (rather than the parallel hierarchy of vowels in unaccented moras) is as given below.

(15) *ACCENT/i >*ACCENT/i,u > *ACCENT/i,u,e > *ACCENT/i,u,e,o

By including all of these constraints, as well as their *UNACCENTED/V counterparts, it is possible to predict the observed patterns of variability in these sequences. However, it is impossible to do so with a strict ranking of constraints: stringency constraints are unable to produce the necessary "ganging up" effects (Farris-Trimble 2008; Jesney and Tessier 2009). I propose, then, that the phenomenon of accent shift is best described using *weighted* rather than *strictly ranked* constraints, as in MaxEnt Grammars (Hayes and Wilson 2008). Constraint weights must be at approximately the levels indicated in (16); note the use of the > symbol rather than ≫ to indicate that the each constraint in a tier has an appreciably lower weight than any weight of a constraint in the tier above it, rather than strict domination relationships among constraints.

(16)

*ÝV
>
ACCENT/i,u,e , *UNACCENTED/a,o
>
ACCENT/i , *ACCENT/i,u , *UNACCENTED/a
>
ACCENT/i,u,e,o , *UNACCENTED/a,o,e , *UNACCENTED/a,o,e,u , etc. (inactive)

Because of the way that I have set up these stringency constraints—which, again, are identical to those proposed by de Lacy (2004) with the exception of their reference to backness-based sonority differences—all sequences observed or predicted to exhibit some degree of accent shift will, if given penultimate accent, incur a violation of both *ACCENT/i,u,e and *UNACCENTED/a,o. Although *ÝV is given a higher weight than either of these constraints, their combined violation will produce a high enough combined violation weight (a gang-up effect) to allow the antepenultimate accent output to become viable; other sequences will not receive pressure toward antepenultimacy from these constraints, and therefore will always be pronounced with penultimate accent. Among the sequences thereby allowed antepenultimate accent, the degree of acceptability of that accent will depend on the number of accumulated violations of the lower-weighted constraints *ACCENT/i, *ACCENT/i,u, and *UNACCENTED/a: only with all three violated will their combined weight be enough to force categorical accent shift ([ai]), and fewer violations of these produce less antepenultimate accent ([ae] and [oe]). (17) gives example tableaux; note that vertical lines do not indicate strict domination. Winner percentages are given in approximation.

(17)

		*ÝV	*Accent/i,u,e	*Unaccented/a,o	*Accent/i	*Accent/i,u	*Unaccented/a
100%	ái	*					
0%	aí		*	*	*	*	*
70%	áe	*					
30%	aé		*	*			*
40%	óe	*					
60%	oé		*	*			
0%	áo	*		*			
100%	aó			*			*
0%	úi	*	*			*	
100%	uí		*		*	*	
0%	ée	*	*				
100%	eé						
0%	úo	*	*	*		*	
100%	uó						

Although the scope of this paper precludes deeper investigation of the implications of such an analysis, the sketch provided here is sufficiently robust as to make concrete predictions about accent shift in other vowel sequences in Japanese. Specifically, it predicts that [au] will have rather high shiftability, that [ou] will be shifted at approximately the same rate as [ae], that [ui] will never shift, etc. This analysis also predicts that the sequence [oi], despite being found only in one non-shifted word in the Japanese lexicon, will nevertheless exhibit a high degree of shift in novel words. These predictions are summarized in (18), in which a blank cell indicates no shift and a higher number indicates a higher probability of antepenultimate accent.

(18)

$V1 \backslash V2$	a	o	e	u	i
a			2	3	4
o			1	2	3
e					
u					
i					

Because many of these sequences are not found in Japanese verbs, it is impossible to test this prediction by looking at actual Japanese forms. In order to evaluate whether the linguistic knowledge of native Japanese speakers recapitulates the analysis I have described here, it was necessary to carry out a test of accent location judgments on novel Japanese words. The following section describes this test.

4 Methods

Probing phonological judgments with novel ("nonce") stimuli can reveal aspects of linguistic knowledge that would otherwise remain hidden from the researcher (Berko 1958; Zhang and Lai 2008; Becker et al. 2012). The basic protocol of such an experiment—in which native speakers of a language are asked to explicitly or implicitly rate the relative acceptability of different potential forms of novel words—is also appropriate for investigating the question of what generalizations Japanese speakers have formed

about accent shift patterns among verbs.

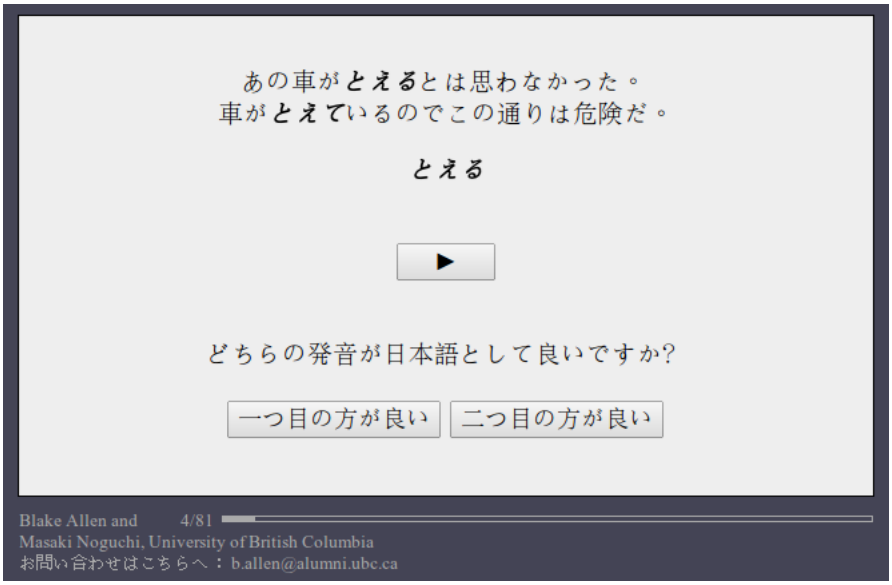
As shown in (5), many of the twenty-five logically possible vowel-vowel sequences are not attested in Japanese verbs, and all of those attested sequences include at least one verb in the accented class. The analysis I have given in the previous section makes strong predictions about the responses native Japanese speakers will offer regarding these novel words which include these unattested sequences, as well as their responses about novel words with observed sequences like [ai] and [ae].

4.1 Procedure

Testing was carried out using an online questionnaire created with Experigen (Becker and Levine 2012). On each testing screen after the instruction frames, subjects first saw a real or novel verb in isolation, as well as two short sentences demonstrating its use in different conjugated forms in order to enhance the sense that these novel words are "real" Japanese verbs, as well as to give information on which conjugation class each verb belongs to. All test novel test items were presented in the *hiragana* orthography. These sentence contexts themselves were also intended to force acceptance of novel forms as Japanese verbs. When finished reading these sentences, subjects pressed a button that played two recorded pronunciations of the target word, which differed only in location of accent: either moraically penultimate or antepenultimate. Subjects were allowed to press the button to listen to the audio tokens as many times as needed. The order of the two recordings was randomized, as was the order of the stimuli overall.

After hearing the target word recordings at least one time, subjects were presented with two buttons with which to indicate their judgments about the relative acceptability of the two pronunciations. These buttons constituted a forced-choice task, in which subjects had to indicate a preference for either the first pronunciation or the second before proceeding. The set of buttons was also labelled as such on each frame. The image in (19) shows a sample screen of the experiment.

(19)



Subjects additionally provided demographic information and comments at the end of the questionnaire, which were used in conjunction with their judgments about real word accent patterns to determine whether any subjects' responses should be discarded. Twenty-nine subjects participated in total, and three subjects' data were excluded based on failure to accept accent shift on at least one of the lexical items canonically produced with antepenultimate accent (*hairu*, *mairu*, or *kaeru*). These exclusions put the total number of subjects in the result data at twenty-six. No subjects were excluded on the basis of provided demographic information.

Subjects were recruited by via postings on student mailing lists, both at the University of British

Columbia and several universities in Japan. Subjects were roughly balanced in terms of gender, and were raised primarily in the central prefectures of the island of Honshuu. Ages ranged from 21 to 47, with a mean age of 34.

4.2 Stimulus Design

Stimuli were comprised of recorded productions of 145 words, 125 novel and 20 real Japanese verbs. Recordings were produced by a native speaker of Japanese with training in linguistics. Of the 125 novel words, 25 were distractor items of the form CVCVCV; all other novel words were CVVCV and therefore eligible for accent shift. These 100 words were four blocks of 25 forms each—one for every possible vowel-vowel combination in Japanese. The four blocks correspond to four different verb conjugations; some conjugations are used more often for integrating loanwords into Japanese, and so it was necessary to control for potential nativeness effects.

Real Japanese words are included in the questionnaire in order to test the reliability of previous literature on their accentual patterns, and as a means of determining which subjects' Japanese may not be close enough to Standard Japanese for their data to be admissible. These words all lacked a consonant between the antepenultimate and penultimate vowels, and included at least one word with each vowel-vowel sequence in this position in Japanese. Some sequences were represented by both an accent shift verb and a standard accent verb, and in the case of [ae], verbs of all three shift-types were included.

Each subject was presented a random set of twelve items out of the twenty-five that comprise each set: the four tested conjugation classes (v-stem verbs, *-nde* verbs, *-tte* verbs, and *-ite* verbs) and distractors. Subjects were also presented twelve random real words out of the set of twenty-two, putting the total number of items per subject at seventy-two. Sessions averaged ten to fifteen minutes in duration.

5 Results

Subjects did not respond in line with the predictions of the sonority-based analysis—at least not in its most literal form. Only 28.8% of subjects indicated a preference for accent shift on novel words with an [ai] vowel sequence, for example, which while significantly greater than such responses for other items, is far from the categorical response that I have predicted. Given this fact, in this section I investigate a *gradient* version of the sonority-based hypothesis in which, despite an overall preference for penultimate accent, sequences with higher predicted shiftability will show a significant trend in that direction compared to other sequences. To look at overall sonority-based patterns irrespective of inter-subject variation, I coded responses as a boolean factor and fit mixed effects logistic regression models, which included random intercepts for each subject, to evaluate the significance of each relevant variable level or combination of levels. A p-value of $< .05$ was taken to indicate significance. All statistical tests were performed using R (R Core Team 2013), and mixed effects models were built using lme4 (Bates et al. 2013).

5.1 Responses on Real Words

Because the premise of this experiment relies on subjects having knowledge of accent patterns in real Japanese verbs that is comparable to to that found in the Japanese Pronunciation and Accent Dictionary (NHK 1985), it was necessary to test subjects' judgments about real words in addition to those about the novel items. These responses did generally reflect the accent patterns listed in the dictionary, as shown by the examples in (20).

(20)

word	*shift status*	*"shift" responses*	*response count*
hairu	categorical shift	100%	12
mairu	categorical shift	70%	10
kaeru	categorical shift	84.6%	13
kotaeru	variable shift	41.2%	17
otoroeru	variable shift	30.8%	13
niou	no shift	0%	15
ieru	no shift	0%	13
aoru	no shift	5.6%	18
oiru	no shift	0%	14

Unexpectedly, the word *mairu* exhibited significantly less antepenultimate accent responses than *hairu*, which all included speakers agreed has antepenultimate accent. Accent location for *kaeru* is midway between those for *hairu* and *mairu*, although not statistically significantly different from either. This difference between *hairu* and *mairu* most likely stems from their different frequences: *hairu* 'enter' is extremely frequent, whereas *mairu* 'to go/come humbly' is less frequent and virtually always used in a conjugated form with different accent patterns (*mairimasu* etc.).

In order to test for significant differences in responses across these three types of words, I constructed mixed effects models of only the real word items, both with the "no shift" response level as the intercept and with the "categorical shift" level as the intercept, as shown in (21) and (22), respectively. These tests indicate that categorically shifted, variably shifted, and non-shifted words do behave differently from each other, as expected.

(21)

Coefficient	Estimate	SE	Pr($>\|z\|$)	
(Intercept: no shift)	1.6386	0.5212	0.001666	**
categorical shift	-3.8610	0.6877	1.97e-08	***
variable shift	-1.0623	0.3131	0.000691	***

(22)

Coefficient	Estimate	SE	Pr($>\|z\|$)	
(Intercept: categorical shift)	-2.2224	0.8081	0.00596	**
no shift	3.8610	0.6877	1.97e-08	***
variable shift	2.7987	0.6755	3.43e-05	***

Subjects do *not* divide neatly into one group that tends to shift variable-accent words and another that does not. Rather, although some subjects tend to prefer shifted accent on more variable-accent words than others, there is no discernible logic behind these responses for each speaker. This finding provides clarification of the reports of variable accent location in the Japanese Pronunciation and Accent Dictionary (NHK 1985): rather than some speakers consistently exhibiting shifted accent on some words and other speakers consistently exhibiting default accent on them, each individual speaker understands each word as variable in accent location, although perhaps not uniformly across all variably accented words.

I conclude from the results in this subsection that the assumption underlying my nonce-word study is a valid one: knowledge that native speakers of Japanese possess regarding accent patterns on real Japanese verbs is consistent with the annotations reported by the NHK (1985).

5.2 Responses on Novel Words

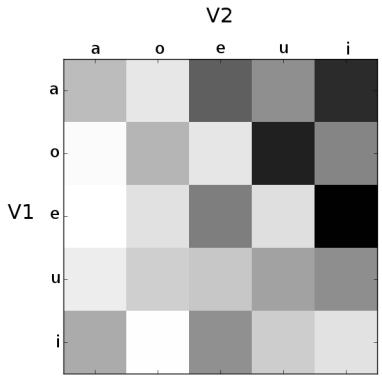
The results on novel word stimuli indicate that participants primarily responded in accordance with the sonority-based hypothesis, and that knowledge of accent patterns in the Sino-Japanese lexical stratum was also called upon during the experiment. Responses indicating a preference for antepenultimate

accent are summarized in the table in (23) and represented graphically using a heatmap (darker cell ∼ higher antepenultimate accent preference) in (24).

(23)

$V1 \backslash V2$	a	o	e	u	i
a	11.6%	6.3%	22.5%	16.9%	28.8%
o	4%	12.5%	6.5%	30.2%	18.2%
e	3.6%	7%	19.1%	7.1%	34%
u	5.8%	9.3%	10.2%	14.6%	16.9%
i	13.7%	3.6%	16.7%	9.6%	7%

(24)



One notable aspect of this per-sequence result overview is that the sequence [oi] has been given a relatively high level of accent shift acceptability. This accords with the sonority-based analysis but not with a putative phonologization of *ói based on the word *oíru*. In other words, the general pattern—which I will show to be based on relative vowel sonority—has taken precedence over the effect of this single exceptional item, and so the existence of the single item *oíru* is not sufficient to undermine the analysis proposed here.

In order to test the stringency-based hypothesis, I fit a logit mixed model with the following predictors:

(25)

1. *sonority difference*: the "raw" sonority difference between V_1 and V_2
2. *crosses o→e*: a binary variable indicating whether or not the sonority levels of the sequence "cross" the crucial boundary I have posited between [o] and [e]
3. *Sino-Japanese seq.*: a binary variable indicating whether or not the sequence is observed in Sino-Japanese morphemes

The sonority difference predictor was set up so as to indicate phonetic difference: it was calculated as (V_1 rank - V_2 rank) on the 5–1 (descending) scale $a > o > e > u > i$, and therefore ranged from 4 ([ai]) to -4 ([ia]). The "crosses o→e" predictor, on the other hand, is included expressly to test the sonority-based analysis I have proposed: it represents the key difference in phonological sonority betwen { a, o } on one hand and { e, u, i } on the other, parallel to the constraint rankings given in (16). Order of presentation (antepenultimate accent heard first or second) and conjugation type were also included, but failed to show strong independent trends in any direction and so are excluded here.

The interaction effect of *sonority difference* and *crosses o→e* corresponds to the predictions of the sonority-based analysis proposed in section 3. Recall the table of predicted "shiftability" values:

(26)

$V1 \backslash V2$	a	o	e	u	i
a			2	3	4
o			1	2	3
e					
u					
i					

The six cells are the vowel sequences for which *crosses o→e* is true. Under a hypothetical analysis in which only this binary variable is responsible for accent shift patterns (comparable to the "pseudo-Japanese" described in the first part of section 3.2), all sequences in one of these six cells would allow accent shift, and the remaining 19 cells would disallow it. Under an account appealing only to raw sonority difference (the *sonority difference* variable), we would arrive at the set of predictions shown in (27). Setting aside the question of whether cells with negative values could be experimentally differentiated from those with zeroes, there are also four cells with positive values which are not present in (26): [ao], [eu], [ei], and [ui].

(27)

$V1 \backslash V2$	a	o	e	u	i
a	0	1	2	3	4
o	-1	0	1	2	3
e	-2	-1	0	1	2
u	-3	-2	-1	0	1
i	-4	-3	-2	-1	0

The interaction effect of *sonority difference* and *crosses o→e* is the subset of (27) that is also in the six cells picked out by *crosses o→e*, and zero for all other cells: exactly the table shown in (26). It is possible, then, to determine whether the analysis I have proposed based on stringency constraints is truly a more accurate description of Japanese speakers' knowledge than an account based on raw sonority difference by comparing these two models using R's ANOVA function. This comparison is shown in (28), where the additional degree of freedom in the *stringency-based* model is the interaction effect of *sonority difference* and *crosses o→e*. The effect of being a licit Sino-Japanese intramorphemic vowel sequence, which will be discussed below, is omitted from these models: they are limited to only the sequences that do not occur in Sino-Japanese morphemes. This omission (rather than the addition of an additional factor) is due to the built-in constraints of the lme4 package in R (Bates et al. 2013).

(28)

Model	Degrees of freedom	Log-likelihood	Pr(>Chisq)	
raw sonority difference	8	-253.81		
stringency-based	9	-251.03	0.01831	*

This comparison indicates that the stringency-based predictions are a significantly better fit to the experimental data than a model based on only raw sonority difference, even when the latter model includes a (non-interacting) effect for *crosses o→e*. Limiting the raw sonority difference variable to only non-negative values and comparing these models also yields a significant advantage (Pr = 0.04347) for the stringency-based model.

In order to achieve a fuller picture of which factors are affecting subjects' judgments, it is necessary to look at a single model that includes all of the above variables as well as the (previously excluded) binary *Sino-Japanese seq.* variable. The parameters of the resulting model are shown in (29):

(29)

Coefficient	Estimate	SE	Pr(> |z|)	
(Intercept: crosses o→e = FALSE, S-J seq. = FALSE)	2.8109	0.45251	5.24e-10	***
sonority difference	0.05293	0.09898	0.59281	
crosses o→e	0.60520	0.76642	0.42974	
Sino-Japanese seq.	-0.88480	0.32026	0.00573	**
*son. difference * crosses o>e*	-0.71602	0.30370	0.01839	*
*son. difference * S-J seq.*	-0.64256	0.24377	0.000839	**
*crosses o→e * S-J seq.*	-1.93931	1.13951	0.08878	
*son. diff. * crosses o→e * S-J seq.*	1.36998	0.45280	0.00248	**

This model is consistent with a combined analysis of vowel hiatus accent patterns which makes reference both to the sonority-based hypothesis described in Section 3 and the accent patterns in Sino-Japanese morphemes. Independent from sonority differences, whether a sequence is found in Sino-Japanese morphemes has a strong correlation with that sequence's accent shift acceptability, suggesting that despite the experiment using only "native Yamato" nonce-words, Sino-Japanese phonotactics were employed in making judgments about them. As the interaction between *sonority difference* and *Sino-Japanese seq.* shows, sonority difference is also predictive of accent shift judgments on sequences that are observed in Sino-Japanese morphemes.

One might wonder why, given the fact that stimuli were presented as Yamato verbs, the phonotactic patterns of Sino-Japanese morphemes proved relevant to subjects' judgments. One likely explanation is that a very limited number of verbs are formed *from* Sino-Japanese morphemes by the addition of a final *-ru*, *-su*, *-zu*, or *-suru*, and accent position on the Sino-Japanese root of these verbs usually remains unchanged. Hence the distinction between Yamato verbs and Sino-Japanese non-verbs is, in practice, of heuristic utility at best. This is especially true considering that many experimental stimuli included vowel sequences like [uu] which are only ever found in Sino-Japanese (or recent loanword) morphemes.

As an additional note, [ei] and [ou] both had a higher accent shift acceptability than even [ai], despite [ai] being categorically shifted both in Yamato words and Sino-Japanese morphemes. I propose that this unexpected result comes about from influence of orthographical factors: the orthographical sequences <ei> and <ou>, which are phonetically and phonologically equivalent to [ee] and [oo], are found intramorphemically only in Sino-Japanese words. Seeing items written this way, then, likely caused many subjects to refer to their Sino-Japanese accent pattern judgments, which would dictate that accent is on the first mora of the sequence. Refer back to section 2.2 for details.

6 Conclusion

This paper has presented a novel analysis of hiatus-conditioned accent "shift" in Standard Tokyo Japanese: that the acceptability of antepenultimate accent rather than the more common penultimate accent is directly correlated with the sonority difference between the antepenultimate and penultimate vowels. Specifically, I have claimed that the observed patterns of variability in these accent patterns can be predicted by de Lacy's (2004) theory of vowel sonority stringency hierarchies and markedness conflation, but only with the crucial additions of phonological sonority distinctions based on vowel backness and the use of weighted constraints rather than strictly ranked ones (Hayes and Wilson 2008). This paper has also described the methodology and results of an experiment designed to test whether native speakers of Japanese use this same principle in their judgments about acceptable accent placement on novel Japanese words, especially those with vowel sequences unobserved in the Japanese lexicon. Analysis of the experimental data indicates that subjects refer to sonority differences in making their judgments, not only in a straightforwardly phonetic way but rather in a way consistent with the specific predictions of the analysis proposed here. The experiment also provides evidence for the use of knowledge about Sino-Japanese accent patterns in addition to knowledge about the Yamato words to resemble which the stimuli were designed.

As a contribution to Japanese phonology in particular, the analysis and experimental data presented here additionally serve to clarify the *loanword accent rule* in Japanese, first proposed by McCawley (1965): “Put an accent on the syllable containing the antepenultimate mora." This rule has since been extended to account for native Yamato accent patterns by Kubozono (2008), but there has been little investigation of which sequences of vowels, especially non-geminate vowels, can be considered tautosyllabic. Assuming that accent position does correlate to syllabic constituency, this paper concludes that there are no categorical criteria for tautosyllabicity among vowel sequences, but rather than syllabicity is evaluated gradiently according to the same phonotactic principles as accent in verbs with vowel hiatus. Perhaps this finding indicates that other phenomena traditionally considered bases for positing phonological syllables in Japanese (Itô 1991; Haraguchi 1996) can also be parsimoniously explained as the result of positional phonotactic restrictions on low-sonority segments.

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Appendix: List of Stimuli

Stimuli are provided in the Hepburn romanization system.

Nonce-words					**Real words**	
Godan-doushi:			*Ichidan-*	Distractors:		
-tte	*-nde*	*-ite/-ide*	*doushi:*			
taatsu	haabu	kaagu	daaru	nadaku	aogu	‘to look up (at)’
yairu	yaimu	kaiku	airu	maniru	aoru	‘to fan’
wauru	naubu	saugu	dauru	tabusu	hairu	‘to enter’
maetsu	waemu	naeku	yaeru	tasetsu	ieru	‘to recover’
saoru	saobu	haogu	waoru	kabomu	kaeru	‘to return’
iaru	hiamu	iaku	kiaru	iwaru	kazoeru	‘to count’
chiiru	miibu	hiigu	iiru	hiriku	kotaeru	‘to answer’
hiuru	kiumu	miugu	hiuru	shimuru	kuiru	‘to regret’
nietsu	chiebu	shiegu	chieru	kitemu	mairu	‘to go (hum.)’
shiotsu	iomu	iogu	nioru	chigoru	niou	‘to smell’
tsuaru	nuabu	muagu	guaru	urasu	oiru	‘to age’
nuitsu	kuimu	fuiku	nuiru	tsuniru	shiiru	‘to force’
nuuru	tsuubu	suugu	muuru	fuzugu	taeru	‘to endure’
tsueru	muemu	nueku	tsueru	nubesu	tooru	‘to go through’
fuotsu	suobu	tsuoku	yuoru	tsumoku	ueru	‘to starve’
earu	heamu	seagu	hearu	sedaru	ureeru	‘to grieve’
neitsu	neibu	heigu	keiru	mebiku	uruosu	‘to moisten’
seuru	keumu	meugu	heuru	ebusu	machigaeru	‘to be mistaken’
meetsu	neebu	eegu	teeru	nekeru	osaeru	‘to restrain’
teotsu	eomu	seogu	georu	hegoru	otoroeru	‘to weaken’
soaru	yoabu	toagu	moaru	sobaru	totonoeru	‘to arrange’
toitsu	hoimu	noiku	hoiru	moshitsu	uttaeru	‘to sue’
koutsu	moumu	hougu	touru	noguru		
noeru	toebu	moeku	toeru	omebu		
nootsu	soomu	toogu	sooru	homoru		