Mayan Morphosyntax
Clifton Pye

Acquisition of Mayan Morphosyntax
Clifton Pye

Spanish Present Subjunctive Usage
by US Spanish Heritage Speakers
Kristi Hixpipe

Light Verb vs as a Little v
Dakkyo Jung

Effects of Context F0 Range in Perception and
Production of a Lexical Tonal Distinction
Evans Wade

Acentic and Perceptual Evidence of
Complete Neutralization of Word-Final
Tonal Specification in Japanese
Kazumi Matsuda

Do Mass Nouns Constitute a
Semantically Uniform Class?
David Nicolas
EFFECTS OF CONTEXT ON RANGE IN PERCEPTION AND PRODUCTION OF A LEXICAL TONAL DISTINCTION

Travis Wade
University of Kansas

Abstract: Fundamental frequency range is generally considered a variable, non-linguistic element of speech intonation. This study examined whether absolute F0 is predictable based on previous intonational context and is perceptually significant. Tokyo Japanese speakers produced sentences pairs differing linearly in the presence/absence of one pitch accent, as responses to speech cues. F0 placement of high tones was consistent across speakers and uniformly dependent on the cue intonation. Continuous manipulation of these sentences between typical accent and non-accent-containing versions were then presented to Japanese listeners for lexical identification. Perception was not significantly altered in compensation for artificial manipulation of preceding intonation. Results are generally consistent with the notion that pitch does not vary gradually across speakers and situations but constitutes a predictable part of the phonetic specification of tones.

Introduction

It might be said that research involving phonetic description of intonational contours has required less quantitatively precise goals than similar study relating to segmental units. For speech segments, amplitude, spectral, and temporal properties have been observed with sufficient precision to characterize contrastively most or all of the sounds of any particular language, across phonetic environments, utterances, and speakers. With pitch, a speech intonation, however, descriptions in the fundamental frequency (F0) dimension tend to be exactly explicit enough to admit the two generally accepted phonemically contrastive units: relatively high (H) and relatively low (L), pitch levels. The details of actual pitch realization (and perception) are explained in terms of the implementation of rules regarding heights of H and L accents relative to each other in various combinations and to their position in a phrase but assumed in general to be highly variable.

Perhaps, as summarized by Cottermnoen (1999), at least part of this variability is due to the participation of non-linguistic factors such as relative prominence in the "intoned phonetic space" (e.g., exact F0 placement of an H tone peak) not required for contrasting between phonemic units in intonation. However, the relative success across languages with which studies of...
example) downstate have modeled typical relationships between tones within an
ultimately suggests that more precise measures of vocal F0 placement than relative
high or low intonation and compare to their specifications. This study deals
with such a possibility, investigatory (1) ways in which these may non-
randomly vary their precise overall pitch range (i.e., the level of their (1) tone
levels) to match or align with others thought to be communication, and (2) the
extent to which these prepared relationships and those previously observed
(whilst/zeinian) downstate patterns may play a role in perception of the tones.
For this latter question, the effects of previous common intonation on the
perception of words is a lexical concept in Japanese based substantially on the
presence of a H tone are observed. Therefore, the interregional types of intonation,
as viewed in the influential Backlund and Younghusband (1966, 1978) tradition
(currently represented by the J. ToBI labeling system; see Vendler 1958 [for conditioning])
is briefly described below.

In J. ToBI analysis of Japanese intonation, prosodic contours are assumed
to be largely underspecified for tone; tendency or earlier descriptions, such syllable
or tone need not have its (1) tone (and, instead, there are a number of
factors which are assumed to be linked to the acoustic phonetic node in the
phonology hierarchy) phonetical tone appears at the beginning of such phrase and
is usually applied to the second stage of the phrase, and a boundary change occurs
at the end of one phrase, according to be the initial syllable of a subsequent
phrase. Additional boundary tones appear at higher levels of a phrase hierarchy.
In addition to these phrase levels, a segmental, lexically determined pitch
against may attach to any word of a word, in has been variously labeled
as H1, H2, H3, and H4 and similar to the H accents used for loan in English,
despite that its presence and location are entirely tonologically determined. This pitch
certainly carries a clear distinctive functional load in current Japanese, evident in
the relative number of minimal pairs where is in contrast (see Kitagawa and Amagai
2000), its role in word recognition in native priming experiments (see Butler
and Oake 1999), and the lasteat it is categorically perceived (Ishii 1982).

A more detailed description of an accent-normal accent contrast characteristics
the description completely of "the second stage phrase displays prominence falls in
pitch starting near the end of the accent contour, while the unaccented phrase
looks like a flat" (Vendler, [phonotonic], this suprasegmental push in the phonetic
literature on pitch accent is, since Piekazan and Backlund 1966, 1968)
showed that, in principle, the accent prominence is distinctly higher, and its category
in cases of phrase containing lexical accent, this indicates that the H4, indeed
defined from a phrase H2 rise, Stigma (1963) described, among other things, that
If0, rather than a combination of pitch and intonality, is the primary cue to accent
perception. Limtrakos, Kimura (1999) reports that segmental differences between
the two accent types do not play a role in their perception. Exploring Stigma’s
notion of accent (1964 flat) and variation in temporal location of the linking
contour, Hasegawa and Hase (1992) suggest that, more specifically, the F0 peak and the slope of the following fall are the primary cues in perception. However, they only deal with the timing (not the F0 value) of the peak, establishing a possible compensatory relationship between peak location and F0 slope in accent location perceptions, and do not consider accent presence perception, where F0 levels are more relevant. Kitaoka (2001) found no effect of slope between normalized H and L values and attributes Hasegawa and Hase's finding to methodological concerns. In a perceptual study involving variation in H and L F0 values and slope of falling contours across various degrees of devolving, Kitaoka suggests there are three perceptual cues to accent perception: pitch at the H and L tones and a falling contour between the two tones. When one or more of these is missing, the others must be used to determine presence and location of an accent.

It seems clear, then, that (F0-determined) presence of an H tone is substantially, but usually not conclusively, responsible for indicating the presence of a pitch accent. This seems to constitute no ideal situation for examining the extent of possible accent effects on the perception of precise tone height; listeners expecting a certain H-to-H peak F0 relationship across phrases and/or utterances might alter a lexical distinction boundary in compensation for changes in context-providing pitch, but would not be forced to do so as this peak does not constitute the only means of identifying the accent. For this reason, the production and perception studies discussed below make use of this pitch accent contrast in investigating (1) whether speakers place the H peak components of pitch accents and accentless phrases, and therefore the lexical distinction between the two, consistently with relation to the intonation of an interlocutor, and (2) the extent to which any such regularity might play a role in perception of the contrast.

Production Experiment

A production experiment was first conducted to observe possible influences of content-providing pitch range on the specific F0 placement of H tones. Its goal was to find regularity which could be predicted—in a manner generalizable across speakers—by preceding intonation in a realistic, pseudo-discourse situation.

Methods: As with all studies presuming to address natural patterns in production of speech intonation, the method of elicitation was a major concern. As Beckman (1987) observes, current models of prosody were originally developed using "read speech", but such productions lack many aspects of spontaneous speech, suggesting methods of more reliable variation, from natural but structured narratives to more uniform but more artificial human-computer interactions. In looking for context-dependent, cross-speaker regularity in production of specific pitch contours, some spontaneity in this study had to be sacrificed in providing that all speakers produced the same words in the same context; with this
limitation, citation was designed to be as realistic as possible. Recordings were made of native speakers producing a simple (but not mutually exclusive) question or request, listed in appendix A. Subjects heard these prompting questions, at a rate they determined interactively, and answered questions or completed with requests using instructions read via an audio cassette. The examiner then noted in writing form always accompanying (or commented) this information, but subjects were instructed to answer or respond to the prompting sentences rather than simply read the text. Also, subjects were allowed to practice and familiarize themselves with the signals before the experiment, so that as little reading as possible was necessary during the test.

Materials consisted of 16 pairs of native Japanese sentences or minimal phrases containing (1) the presence or absence of a single (11th) pitch accent. These pairs (listed in appendix B) vary greatly in total length, location of accent contour, accentual syllable structure, and other features of phonemes surrounding accentual vowels. Some of these contours were introduced for the purposes of the experiment as described below; in general, the rest were present in order to account for various phonetic factors (segmental and otherwise) that might affect the F0 stage at which particular F0 accents and ensure that a difference in similarity between groups was not due to such factors.

The same recordings of the 16 prompting sentences were used for all productions (acoustic subjects, sentences, and repetitions) in the experiment. They each were spoken by the same adult female speaker of Japanese; all productions were recorded, and a natural-sounding token of each was chosen such that overall pitch range varied significantly between the two. In the experiment, each production was prompted by instructions (oral and auditory cues) presented by computer. Once subjects observed a cue, they responded by speaking an indicated word or sentence into a microphone and pressed a key in order to proceed to the next stimulus. Each task was allotted three times to each subject. Stimuli were randomized separately for each subject in three blocks representing growth of words indicated in appendix B, in a single recording session. Auditory prompts were administered through computer speakers (not loudspeakers) so that subjects could hear their responses in a natural manner. Recording was done in the Kansas University Phonetics and Psycholinguistics Laboratory (KUPILL) in a sound-treatment room using a microphone and high-quality cassette recorder, and recordings were digitized and later manipulated by computer using the speech analysis program Praat (Copyright 1998–2004 by Paul Boersma and David Weenink). Subjects were 7 native speakers (6 female, 1 male) of native Japanese, ranging in age from 18 to 34 years. Native reported a history of speaking or hearing difficulty. One speaker's results were discarded due to inability to make several acoustic results of the remaining 6 are presented below.
Predictions: As a purpose of the experiment was to observe an effect of intentional context on the production of particular of H peak levels, the following null hypothesis was assumed:

H0-1a: H* peak frequencies will vary continuously across productions and subjects, with no significant differences depending on the prompting utterance.

To reject this hypothesis, then, peak frequencies would have to be similar or observably related across and within subjects and differ depending on the type of prompt used.

Addressing whether context affects the distinction location between accented and unaccented forms is slightly less straightforward; target syllables of unaccented forms, lacking pitch specification, should occur as a variety of possible pitch locations determined by their place in the phonologically defined contour and thus appear as variable distances from their more fixed H* counterparts. As, however, the F0 location of the phrasal H tone plays a large part in determining pitch level throughout the phrase, and many accent continua usually occur in the (second mora) H location, this value was considered a measure of F0 scaling its unaccented words. For this reason, the following additional null hypothesis was formed:

H0-1b: Phrasal H peak frequencies will vary continuously across productions and subjects, with no significant differences depending on the prompting utterance.

In order, then, for a shift in the location of the accent presence distinction to have taken place, both of these hypotheses had to be rejected, with context-determined differences occurring in the same direction.

Results: Table 1 shows individual speakers’ average placement of H peak frequencies for each phrase, followed by standard deviations of means and a relative measure of overall variance. Perhaps most immediately notable is the small within-subject variation in range. Within an accent or prompt condition, F0 location of contour peaks typically differs well under one semitone from a relevant mean, or by only a few percent of the height of the peak itself.
Table 1: Individual speaker H peak Fl for 3 repetitions of sentences 1-5 (group 1) and 6-9 (group 2)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Peak for prompt 1</th>
<th>Peak for prompt 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD (Mean)</td>
</tr>
<tr>
<td>S1</td>
<td>H accented</td>
<td>205</td>
</tr>
<tr>
<td></td>
<td>[] pronate H</td>
<td>231</td>
</tr>
<tr>
<td>S2</td>
<td>H accented</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>[] pronate H</td>
<td>137</td>
</tr>
<tr>
<td>S3</td>
<td>H accented</td>
<td>304</td>
</tr>
<tr>
<td></td>
<td>[] pronate H</td>
<td>356</td>
</tr>
<tr>
<td>S4</td>
<td>H accented</td>
<td>276</td>
</tr>
<tr>
<td></td>
<td>[] pronate H</td>
<td>261</td>
</tr>
<tr>
<td>S5</td>
<td>H accented</td>
<td>270</td>
</tr>
<tr>
<td></td>
<td>[] pronate H</td>
<td>248</td>
</tr>
<tr>
<td>S6</td>
<td>H accented</td>
<td>356</td>
</tr>
<tr>
<td></td>
<td>[] pronate H</td>
<td>248</td>
</tr>
</tbody>
</table>

More critically, it can be shown that the type of prompting utterance played a predictive role in determining pitch range in both accented and native speakers. Univariate analysis of variance was performed on pitch frequencies for all sentences, and main effects were found for both accent and prompt type. No significant Prompt x Accent type combined effects were observed, indicating that the Prompt effect was stable across prompting type and accentedness.

Table 2: Effects (ANOVA) of prompting and accent type across speakers

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prompt</td>
<td>(1.344)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Accent</td>
<td>(1.344)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Prompt x Accent</td>
<td>(3.024)</td>
<td>.077</td>
</tr>
</tbody>
</table>

This means that both null hypotheses comparing predictor data may be reasonably rejected, and it may be assumed that voice, played a predictable role in the assignment of pitch contour to the productions. Also important, however, is the degree to which these patterns extend across speakers. Based on conversation with subjects, it was observed that subjects S1, S4, S5, and S6 had medium female pitch ranges similar to that of the prompting speaker, while subject S2 had a relatively high female range and subject S3 a medium male range. These last two speakers, who deviated most fluidly from the others in produced imitation, might have used different mechanisms for adapting to the pitch contour provided in the text. Subject S2’s H values, e.g., were consistently
approximately one octave below those of S1, S4, S5, and S6). Excluding subjects S2 and S3, then, notable homogeneity is to be found in the F0 contours of the remaining four, as shown below:

<table>
<thead>
<tr>
<th></th>
<th>Peak for prompt 1</th>
<th>Mean</th>
<th>SD</th>
<th>Ratio</th>
<th>Mean</th>
<th>SD</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th accent</td>
<td>1</td>
<td>247</td>
<td>14.83</td>
<td>0.091</td>
<td>204</td>
<td>13.65</td>
<td>0.048</td>
</tr>
<tr>
<td>phrase H</td>
<td>2</td>
<td>216</td>
<td>14.82</td>
<td>0.098</td>
<td>239</td>
<td>12.74</td>
<td>0.063</td>
</tr>
</tbody>
</table>

Table 3: Average peak values for subjects S1, S4, S5, and S6 combined

Again, typical differences are quite small, especially when compared to absolute means. While additional experiments lacking the speech prompts described above were not carried out, it was assumed that the regularity observed would not be expected from a set of productions assigned pitch based on continuously varying, speaker-defined or otherwise arbitrarily assigned values.

Perception Experiment

Production results suggest that at least both types of H tone levels in Japanese, and therefore the level associated with the categorical distinction between them, may be related to the intonation of preceding context. As discussed above, H peak values are of course not the only cues to pitch accent perception. A following L value and an intervening fall are also key features, and it would be expected that the local context contrast that there exist sufficient acoustic invariance among those cues for accent identity to be unambiguous with or without information from previous context. Still, context is known to have effects on the perception of categorical distinctions in speech even when there is sufficient cues for a categorization to be made (Moore and Johnson 1997, e.g.). It seemed appropriate, then, in evaluating how functional a role context effects may play in in contextual perception, to conduct a perception study based on these same contrasts. It was hypothesized that subjects attending to intonation contours might expect correspondence between H tone levels as uniform in that observed in the production study. Altering context-providing pitch context (or portions of contours) could, then, cause the subjects to compensate for this change when making lexical judgments based substantially on following H tone information. Two typical productions taken from the production experiment were manipulated for F0 in various ways to construct six perception experiments to address this question.

Method: A first set of experiments involved the single utterance Rantan-nor ana/ ana dec, as produced by speaker S-4. This sentence contains two pitch accents, the second of which is involved in an accent contrast. From this second word was created a continuum of F0 values between typical accented and typical
unaccented productions. This continuum then appeared in three different conditions, one (A-1) with only the word and no preceding context, one (A-2) with the word in a natural sentence context, and one (A-3) where the preceding accent peak had been lowered significantly. (In all cases, the final stress was removed.)

The second set of conditions was similar, except that no such within-utterance downstep relationship existed, the target sentence stimulus/data group (as produced by speaker S-6) contained only one possible accent, and content cues in the form of the interlocuter request immediately preceding the sentence. As the first set of conditions, the sentence occurred after a natural (S-2) or an altered (S-3) version of the same interlocuter or else without preceding context (S-1). In this case, the content in condition S-3 consisted of the same utterance transposed (in its entirety) down significantly from its original pitch range.

In all conditions, artificially manipulated contours consisted of straight-line segments including sufficient detail that endpoint stimuli were virtually indistinguishable from the natural tokens used to generate them. In each case, all endpoints of the contours were virtually indistinguishable from the natural tokens used to generate them. Figures 1 and 2 illustrate, as opposed to a set of cross-related continua, with each target varied independently of the others.

Figure 1: Schematic diagram of some parameters varied simultaneously

This was both in the interest of keeping stimulus numbers at a minimum and in order to vary pitch in a more realistic, natural manner. Pilot series confirmed previous reports that both H and L values contribute to accent perception and
suggested additionally that when only one of these cues is varied and the other remains in an optimal accorded or unaccorded position, observably unnatural contours may result. It was also independently determined that the accent type of the token used as the base for pitch manipulation did not affect perception of the continuum, so originally accented tokens were used in all conditions as they were generally clearer.

Each of the six conditions listed above was used to create a separate test; tests involved an identification task across a ten-member continuum; ten repetitions of each token resulted in 100 total stimuli for each test. Subjects were first allowed to listen to the two continua and members until they were confident of their ability to make the distinction, and then listened to the 100 test stimuli in random order, after each responding whether the stimulus sounded like the first or the second endpoint lexical item. Subjects heard each stimulus only once but could progress at any rate, clicking a mouse button in order to hear each stimulus and enter stopping to review example stimuli if necessary, though they were encouraged not to do so in the instructions. Tests were created in web-page format, approximately half were administered in a controlled laboratory setting (KUPPP), while the rest were completed via internet by subjects elsewhere in the United States and in Japan. Subjects were adult native Japanese speakers aged 19 to 50 years. None reported a history of hearing or hearing disability. Subjects were allowed to participate in as many separate experiments as they wished; some took only one or a few tests while others took several.

Predictions: As the goal was to observe possible differences in perception based on H* accent context, the following null hypothesis was adopted:

H0-2: Perception of the pitch accent contrast will not significantly differ between the altered preceding accent case, the natural sentence context, or sentences lacking intonational context.

If listeners' expectations of a consistent peak-to-peak downstep relationship was influenced in their lexical decision, then, location of the accent contrast would differ, presumably being somewhat lower in the case of the lowered previous accent condition.

Results: Perception results for tests A-1 - 3 and S-1 - 3 are shown in figures 2 and 3, respectively (plotted response proportions are averaged across participants).
Figure 2: Averaged responses to nine / nine stimuli

Figure 3: Averaged responses to /iɪk-/ /iɪkt/- stimuli

These rather clear distinctions seem to suggest that subjects did not perform differently across testing conditions. Between-test correlation values of response proportions among stimuli above were nearly perfect in such cases, and, critically, test 3 in each set, in which the preceding innovation was altered and thus any content effect would be observed, did not vary appreciably from either of the other two tests.
In order to look more precisely at possible differences between tests, it was necessary to use a single measure of distinction location that could be treated as a perception score for each subject. Probit regression analysis was first used to transform individual subject response data into curves which used all observed proportions in predicting continuum locations for response frequency values 0.50 crossover points on these curves, then, were used to represent the category boundary for each subject. A summary of probit-predicted distinctions is given below:

<table>
<thead>
<tr>
<th>Test</th>
<th>Average Probit 0.50 Value</th>
<th>SO</th>
<th>Test</th>
<th>Average Probit 0.50 Value with SO</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>0.54</td>
<td>0.47</td>
<td>S-1</td>
<td>0.56</td>
</tr>
<tr>
<td>A-2</td>
<td>0.18</td>
<td>0.46</td>
<td>S-2</td>
<td>0.55</td>
</tr>
<tr>
<td>A-3</td>
<td>0.02</td>
<td>0.59</td>
<td>S-3</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>combined average</td>
<td></td>
<td></td>
<td>combined average</td>
</tr>
<tr>
<td></td>
<td>0.03</td>
<td>0.46</td>
<td></td>
<td>0.54</td>
</tr>
</tbody>
</table>

Table 4: Probit-defined distinction locations

As shown above, standard deviations of within-test means were all much smaller than one continuum member, indicating that there was agreement between subjects as to the location of the distinction. A one-way ANOVA failed to reveal a significant effect of test (one-tailed test: F(2,10)=3.40; p=0.07; Student's t test: t(2,12)=0.91; p=0.36).

It does not appear, then, that subjects were allowing context to influence their perception of the contrast in any way, and the results failed to reject null hypotheses (H₂). The high cross-test agreement shown by the small standard deviations in distinction location suggest strongly that this null finding was not due to the limited number of participants but reflected a genuine perceptual tendency.

Discussion

The present production study results suggest strongly that the pitch content provided by a preceding (promoting) utterance does indeed play a role in the scaling of at least H tone peak frequencies in produced intonation. This is evidenced in that both types of peaks observed appeared in limited ranges which were predictable by prompting type. Such uniformity would not be expected from random or arbitrary assignment, nor would the highly consistent differences between peaks in responses to differing prompting types. This finding is consistent with a view that at least the H level component of overall pitch range...
is, in the presence of previous F0 context, as an entirely gradient, continuous, non-linguistic variable.

Perception results helped to reveal the limits of the importance of such relationships by failing entirely to show differences in the boundaries of a categorical perception based on compensation for changes in pitch context. It was predicted earlier that the vertically aligned pitch accent distinction might be altered to account for perceived relationships with relevant earlier pitch events; the facts that (1) no such effects were observed, either when use (1) tonal context-pitch event (case tests) or an entire prompting context (pitch tests) was altered, and that (2) no effect of any kind was found depending on whether context-providing contours were present or absent, help to show the extent to which tendencies observed in production are heuristic in perception. Technically, it could be either that the cues provided by context-pitch are insufficiently important to effect perceptual changes or simply that the H and L pitch cues present locally within a (fully voiced) accent unit were not salient enough to override at least the types of conflicting context information examined in this study. However, considering the fact that at least qualitative context effects have been observed for pitch accent perception when use local information was available (e.g. Maffi 1993) and the general tendency for sensitivity to unisyllabic representations, clearly adequate cues in the speech signal, it seems likely that the absence of these is the case. That is, of the two types of information available in making the perceptual distinction—previous context information and local H-L relationships—the latter, more immediate one is in this case preferred, where possible, when the two are in contradiction.

The results of this experiment, then, are in general consistent with—but demonstrate the incompleteness of—descriptions of intonational phenomena such as those of Ladd (1996), in which only phonologically informative tones are assumed to autonomously maintain linguistic status. While present F0 scaling of tones may not have the same type of linguistic function as the tones themselves, it appears clear that the phonetic realization of pitch range is predictable to a larger extent than accents is assumed to be, by contextual cues. Present data are by far insufficient to propose a precise system of functional relationships, but it seems in order to assume at this point that some such formulation could result from further study.

Appendix A

Sentences used as verbal prompts for production experiment:

1) kim-wo Ậù đẹ sìntä (for sentences 6-9)
   what is this (a picture of)?
Appendix B
Phrases/ Sentence Pairs for production

1) okawari vs. okasari
   "change" vs. "ascertain"

2) kaikuru vs. kaiketu
   "to lack" vs. "to gallop"

3) kaeru vs. kienu
   "frog" vs. "to return"

4) ame vs. ake
   "raining" vs. "min"

5) shitaai desu vs. shitaai desu
   "dead body" vs. "I want it"

6) akai hachi desu vs. akai hachi desu
   "it is a red bridge" vs. "they are red chopsticks"

7) tosenu hito desu vs. toshiro hito desu
   "he is a person who strops" vs. "he is a rich person"

8) hakaihi desu vs. hikaihi desu
   "it is blank paper" vs. "she is a doctor"

9) minato-no ame desu vs. minato-no ame desu
   "it is candy from London" vs. "it is London mint"

10) kante vs. kante
    "kept as a pet" vs. "keep"

11) katta vs. katta
    "kept as a pet" vs. "bougies", "reaped"

12) uta vs. uta
    "hi" vs. "old"
13) *shimna* vs. *shiminu*
    "closed" / "putting in order"

14) *shinai* vs. *shimaiju*
    "closed" / "putting in order"

NOTES

1 The experiments outlined here represent part of a larger study described in Weeks (2001).

2 With the exception of the second noun of a noun (VV, VN) nuclear and
   the limitation that a word may have at most one accent.

3 As in Mudzuri (1993; as reported by Kitahara, 2001), where with a
   corollary of accent-following L, values in an accent-opposed minimal pair in
   which the accented vowel is voiceless. Listeners' perception followed according to
   preceding context: subjects were somewhat more likely to hear the unaccented
   form when there was a pitch accent quiter in the phrase. Physiologically, as Kitahara
   observes, the difference was due to listeners' accounting for the expectation of a
   downstepped pitch range in the accented context.

4 Of course, these levels also vary with context, particularly if deaccent
   is assumed, however, any such effect would be small in the stimuli used here
   (provided that the H* tone analyzed are not precluded by other accents and thus
   subject to downstep; for this reason, only the initial H* tone is considered in
   instances with multiple accents) compared to the effect of position in an
   unaccented phrase.

5 Specifically, only H* and H peaks from responses to sentences 1-5 were
   used as input for the analysis. Responses to sentences 10-14 had geminate stops
   immediately following the target syllables; as a result, H peaks were somewhat
   higher and less regular in the much shorter vowels and, while useful in creating
   pitch contours, were not considered in production analysis. Similarly, sentences with
   voiceless vowels on the second stress were excluded from phrasal H* analysis because
   of their lack of an observable peak, and H* accents after the third syllable were excluded as a few
   subjects placed additional phrasal boundaries before the accented.
In this and other test groups, sample sizes depended partially on which tests remote subjects opted to take and therefore often differ between individual tests; this does not affect analysis of the results as such groups were regarded as independent samples.

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