

these languages tonal production can be seen to make optimal use of the perceptual contrast between levels and movement by means of critical timing of tonal movement. In other languages where the use of movement features is less clear, this type of synchronization may not be as important. However, the tonal features Low, Falling, and High would seem to fit the data for German presented by Kohler 1987 where changes in pitch peak location through the stressed vowel result in categorical pitch perception of 'established', 'new' and 'emphatic' information respectively.

This model of optimal tonal feature perception is preliminary and somewhat simplified as it contains only four tonal features. An examination of production data from different languages could help expand the model and lead to further perception tests. An awareness of perceptual constraints may facilitate the analysis of production data and improve our description of the contrasts used to distinguish between different tonal features.

REFERENCES

- Anderson, S.R. 1978. 'Tone features'. *Tone: a linguistic survey*, ed. V.A. Fromkin, 133-175. New York: Academic Press.
- Bruce, G. 1977. *Swedish word accents in sentence perspective*. Lund: Gleerups.
- Gårding, E., P. Kratochvíl, J.-O. Svantesson & J. Zhang. 1986. 'Tone 4 and tone 3 discrimination in modern standard Chinese'. *Language and Speech* 29, 281-293.
- House, D. 1987. 'Perception of tonal patterns in speech: Implications for models of speech perception'. *Proceedings of the Eleventh International Congress of Phonetic Sciences*, ed. Ü. Viks, 1, 76-79. Tallinn: Academy of Sciences of the Estonian S.S.R.
- Klatt, D.H. 1980. 'Software for a formant synthesizer'. *Journal of the Acoustical Society of America* 67, 971-995.
- Kohler, K.J. 1987. 'Categorical pitch perception'. *Proceedings of the Eleventh International Congress of Phonetic Sciences*, ed. Ü. Viks, 5, 331-333. Tallinn: Academy of Sciences of the Estonian S.S.R.
- Maddieson, I. 1978. 'Universals of tone'. *Universals of Human Language, Volume 2, Phonology*, ed. J. Greenberg, 335-365. Stanford, CA: Stanford University Press.
- Stevens, K.N. & S.E. Blumstein. 1981. 'The search for invariant acoustic correlates of phonetic features'. *Perspectives on the Study of Speech*, eds. P. Eimas & J. Miller, 1-38. Hillsdale, NJ: Lawrence Erlbaum Associates.

Mora and Temporal-Tonal Interaction in Japanese

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Abstract

When seeking the phonetic realization of the mora, it has been a common practice to measure the acoustic duration on the assumption that it reflects the concept of quantity. It is argued that this duration-only approach is inadequate in certain cases. An alternative approach considering the interaction between temporal and Fo events is suggested to explain the abstract nature of the mora. It is also pointed out that words contrasting in vowel length have a strong tendency to accompany different pitch patterns in those dialects of Japanese that have pitch accent contrast.

INTRODUCTION

When seeking the phonetic reality of the mora, most works study only one of the acoustic dimensions, duration or fundamental frequency contour (henceforth Fo). This paper suggests that in certain cases this one-way approach is inadequate and that looking at the interaction between the two may explain the abstract nature of the mora better.

The phonetic research on the mora has been almost exclusively concentrated upon Japanese. In most dialects of Japanese, the mora is the smallest prosodic unit of tone assignment. The central issue in the description of the Japanese mora is its function as a temporal unit, which has long been controversial. It has been claimed that Japanese moras are pronounced with roughly equal length of time regardless of their internal moraic structure (Bloch 1950, Hockett 1955, Han 1962, Ladefoged 1975). Thus in deliberate speech (e.g. teaching children or foreigners), the words *nippon* 'Japan', *amaoto* 'the sound of rain', and *kjookai* 'church' will be pronounced as [ni-p-po-n], [a-ma-o-to], and [kjo-o-ka-i] ('-' equals mora boundary) respectively, each mora taking about the same time. This principle of pronunciation might have something to do with the moraic writing system in which, except for CjV mora, one *kana* character is assigned to one mora.

Some have recognized the mora as a relevant unit in regulating the Japanese utterances and have incorporated it in their production-oriented timing model (Port et al. 1980, 1987) while others have denied that the mora

has any phonetic reality at all (Beckman 1982). In those studies, the relationship between pitch accent contrast and length contrast are not taken into consideration.

Phonetic realization of the mora as a unit of tone assignment is reported in Mase 1973. Mase attempted to substantiate Rischel's 1974 claim that in West Greenlandic Eskimo, it is the mora rather than the syllable that is regulating the phrase final intonation contour high-low-high. Examples (where '.' equals syllable boundary):

a. k í. v à. r á	a á. v à á	a. t á à. s í q
'I answered him'	'he fetched it'	'one'

Mase calculated the mean F_0 value for each vowel mora and the figures supported Rischel's claim. Mase remarked, though, that it was regrettable that the durational factor was neglected in his study. As for long vowels, he made an arbitrary decision to divide them into two equal halves.

Altogether, the ambiguity in segmenting homogeneous long vowels reflects the abstract nature of the mora. I think the cases from Japanese and from West Greenlandic point to the essential problem in seeking for the phonetic reality of the mora either in temporal or tonal dimensions. If we consider that in certain cases the mora is created by the interaction between the two dimensions, there will be no conflict.

THE COORDINATION AND TIMING OF F_0 WITH SEGMENTALS

The importance of studying the interaction between tonal and temporal phenomena for understanding certain aspects of prosody, in particular accentuation, has been pointed out for some time (cf. Bruce 1983). Below I discuss two concepts which have directly influenced the mora analysis presented in this paper.

First is the concept of the F_0 turning point in the production-oriented model of intonation developed in Lund (e.g. Gårding 1983). This concept requires marking the F_0 maxima and minima in relation to segmentals as a necessary specification in generating a predicted prosodic pattern. A wide success in applying this notion to languages of different prosodic types implies that the point at which the major tonal change coordinates with the segmentals gives certain cues in describing prosody in general.

In a study of Hausa intonation within the framework of the Lund Model of Intonation, Lindau 1986 writes "the maxima and minima of the F_0 contour do

not generally coincide with the middle of the vowel, as one might expect. Instead, there is a strong tendency for the turning points in sentences with alternating highs and lows to occur at, and around, the syllable [mora in our sense, YNM] boundaries". This phenomenon seems to be common in mora-counting languages in Trubetsky's sense (Trubetsky 1969). Similar observations have been made for Japanese and West Greenlandic (Nagano-Madsen 1987, 1988), and informally for a number of Nigerian languages belonging to the Kwa family such as Yoruba, Yagba, and Ivie.

As regards the place of the F_0 turning point, it has been pointed out that despite the number of logical possibilities, it is found typically "(1) on a vowel or (2) at and around the mora- and syllable- boundary depending on whether it is a mora or a syllable that is the unit of tone assignment" (Nagano-Madsen and Eriksson 1989). We would like to alter this statement by deleting 'syllable' and referring to 'mora boundary' alone. This is because what is called syllable in some languages is actually equivalent to mora in other languages, and all the examples cited for category (2), including Hausa, can fall into the group of mora-counting languages in Trubetsky's classification.

Secondly, the tonal-temporal interplay theory presented in Bruce 1981, 1983 has shed light on how F_0 events interact with spectral events in speech to give prominence. Bruce's work was a consequence of a number of studies on Swedish prosody in which one of the issues was a tonal or temporal primacy in modelling prosody. Evidence has been reported for a tonal dependence on temporal demands as well as for a temporal dependence on tonal demands (cf. Bruce 1983 for literature).

Bruce's conclusion was that F_0 and spectral events at the successive stress group boundaries are critically timed, and between these points the timing is not crucial. Seen in this synchronization view, either tonal or temporal primacy in Swedish was found to be non-conflicting. It will be shown that, in mora languages like Japanese and West Greenlandic, the temporal and F_0 events seem to work together for the realization of the mora in some cases.

THE MORA IN PRODUCTION AND IN PERCEPTION

In Japanese, the point of pitch change usually occurs at and around the mora boundary (Fujisaki 1983), and this phenomenon was found to remain constant against tempo and context variations. Nagano-Madsen 1987 studied the constant and varying features in the acoustic manifestation of highs and lows when tempo and tonal context are varied. The result showed that the timing of the F_0 peak and successive fall in relation to the mora boundary was one of the

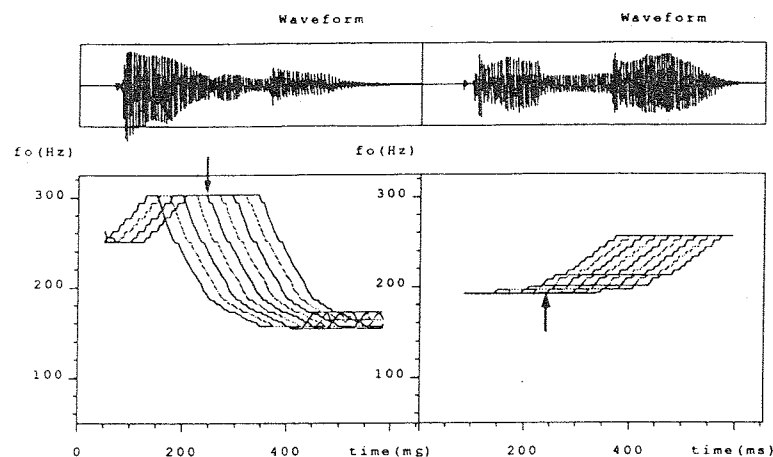


Figure 1. Wave form and fundamental frequency contour of /áma/ and amá/. The arrow indicates the original version. From Nagano-Madsen & Eriksson 1989.

most constant features, while factors such as pitch range and the maintenance of the F_0 at a particular pitch height varied greatly. The F_0 valley and rise showed a similar tendency to be timed at the mora boundary, but with a lesser degree of rigidity.

The significance of this F_0 pattern fixation to the mora boundary was tested perceptually in Nagano-Madsen & Eriksson 1989 by using synthesized stimuli. The original bi-moraic words such as *ama* (*a-ma*), *mama* (*ma-ma*) and *an* (*a-n*) having either HL or LH patterns were manipulated to shift the F_0 fall and rise at every 25 ms from the original mora boundary by using ILS synthesis. There were altogether eight synthesized versions: four moving into the preceding vowel and four moving into the following consonant (cf. Figure 1).

The synthesized versions together with the original were presented to a group of native Japanese listeners to judge if the utterance sounded like the original. The results showed that the timing of the F_0 fall and rise to the mora boundary is important in the sense that when these falls and rises are timed with the central part of the vowel, listeners tend to hear it as two vowel moras, e.g. **aama* (fall stimuli) or **amaa* (rise stimuli) instead of *ama*. This means that the vowel [a] of the same duration could be heard either as mono-moraic

or bi-moraic depending on the F_0 contour it accompanies, e.g. from [ámà] to [ámà] and from [ámá] to [ámá].

The results have at least two implications. First, since a vowel of the same acoustic duration offers the perceptual possibility of hearing either one or two moras depending on the F_0 patterns it accompanies, it may be inadequate to describe the phonetic nature of the mora solely by the acoustic duration. In this respect, I would argue against such a view as that expressed by Hockett, who defines the Japanese mora "fundamentally in terms of duration and nothing else" (Hockett 1955:59).

Second, in a mora language like Japanese, there may be highly restricted timing of F_0 fall and rise to a mora boundary so as not to result in contour tone on a single vowel mora, as this may be perceived as an additional mora. This restriction of timing may be relevant for the phonetic classification of prosodic categories such as quantity, stress, intonation etc. It is interesting to note that Sugito 1980 found that in Japanese utterances by English speakers, the place of pitch peaks tends to be in the vowel rather than at the mora boundary, which makes the intended word [ame] 'rain' sound like as [aame].

In autosegmental descriptions of English (e.g. Pierrehumbert 1980), a stressed vowel can be associated with more than one tone, such as HL and LH. In Japanese, a single vowel mora is always associated with only one tone, and when there are two tone elements, the vowel is divided into two moras. This means that the use of F_0 to convey intonational meaning is very much limited in a language like Japanese. Stressed syllables in English are usually about twice as long as unstressed ones (Lehiste 1970, Klatt 1975), and stressed syllables typically have contour F_0 shapes. On the other hand, in a non-stress language like Japanese, a single vowel mora can not have a contour tone. A contour tone always occurs on a vowel consisting of two moras which is usually much longer than a single mora vowel. Thus the utilization of the duration and F_0 seem to work on the same principle both in English and in Japanese.

The present analysis of mora may have some importance for the description of prosody in general. In the Prague school, the postulation of the mora is closely related to the accent and quantity analysis (Jakobson 1931, Trubetskoy 1969). The classical law of the Prague school says that 'free stress' and 'free quantity' are incompatible in a given language, a law postulated mainly on empirical basis. Recently Anderson 1984 has supported this claim by reinterpreting it within the theory of metrical phonology, regarding stress and quantity as structurally motivated properties. Since the

phonetic evidence of the surface manifestation of stress and quantity as exemplified from English and Japanese has given rise to similar principles both for stress and quantity, it may be possible to explain this classical claim from a phonetic point of view.

LENGTH AND PITCH ACCENT PATTERN

The result of the perception test calls attention to the phonological patterning of length and accent contrast in Japanese. In those dialects of Japanese in which an accent contrast is maintained (e.g. Standard Japanese and Osaka Japanese), accent contrast is found mainly in short words such as bi-moraic and tri-moraic words. In such a dialect, it is not typical to find a minimal pair in which only vowel length is in contrast, while it is quite easy to find a minimal pair contrasting only in consonant length. See the following examples adopted from Young & Nakajima 1981:4,6. Pitch patterns are given both for Standard Japanese and for Kochi Japanese (a variety of Osaka Japanese), the latter being from my own pronunciation.

Vowel length contrast:

	A. Standard	B. Kochi	Gloss
1	[obásáń]	[obasan]	'aunt'
2	[obáasan]	[obáasan]	'grandmother, old woman'
3	[ojísáń]	[ojisan]	'uncle'
4	[ojíisan]	[ojíisan]	'grandfather, old man'
5	[sokó]	[sokó]	'there'
6	[sóoko]	[sóoko]	'warehouse'
7	[bíru]	[bíru]	'building'
8	[bíiru]	[bíiru]	'beer'
9	[béru]	[béru]	'bell'
10	[béeru]	[béeru]	'veil'

Consonant length contrast:

	A. Standard	B. Kochi	Gloss
1	[sakága]	[sákaga]	'a slope is'
2	[sakkágá]	[sakkágá]	'a writer is'
3	[ító]	[ító]	'thread'
4	[ítto]	[ittó]	'one to (unit of measure)'

5	[keçí]	[kéçi]	'poppy'
6	[keççí]	[keççí]	'do-or-die spirit'
7	[itá]	[íta]	'was'
8	[ittá]	[ítta]	'went'
9	[itçíwa]	[ítçíwa]	'number one is'
10	[ittçíwá]	[ittçíwá]	'the agreement is'

In descriptions of Japanese, the length and the pitch pattern are generally treated separately (McGovern 1953, Martin 1954, Young & Nakajima 1981, Vance 1987). Also, it is commonly stated that the length distinction is far more important than the pitch patterns, and foreign learners are recommended to neglect the pitch variations. This is partly because the accent patterns differ greatly from one dialect to another. The two major dialects Standard Japanese and Osaka Japanese often have opposite pitch patterns, as exemplified in [háçi] (S.) / [haçí] (O.) for 'chopsticks', and [haçí] (S.) / [háçi] (O.) for 'bridge'.

However, when we examine the relationship between length contrast and pitch patterns, we note that there are certain regularities. First, as mentioned earlier, it is not typical to find a minimal pair that contrasts only in vowel duration. Words contrasting in vowel length usually accompany different pitch patterns, though there are some exceptions. Second, recent loan words from English are converted to Japanese with very regular length and pitch pattern distinction. In the above examples, the pair [bíru] 'building' and [bíiru] 'beer' belongs to this category. Further examples of long vowels are [kéeki] 'cake', [géemu] 'game', [séefu] 'safe', [téepu] 'tape', [déeto], 'date', [kóodo] 'code', [sóoda] 'soda', [kóosu] 'course', [sóosu] 'sauce', [çóoto] 'short' (examples from Kawakami 1977). Note that all these long vowels have HL pitch pattern, and these words are pronounced exactly the same in both dialects.

In Japanese, there is a set of rules that govern the pitch patterns. They include grammatical categories such as noun, adjective etc., sometimes in combination with the number of the moras in the word, and sometimes with specification of morpheme such as [ko] 'child'. (Kindaich et al. 1988). Considering all such rules as well as the origin of words, I think the relationship between length contrast and pitch pattern is far from being arbitrary. It looks as if the two prosodic categories are patterned so as to reinforce the contrast between the two words.

It is interesting to note that Trubetskoy 1969 has a unique concept of quantity. In the section on prosodic opposition, he repeatedly states that the phonological concept of quantity is not exclusively expressed by length but also by pitch change. He writes:

...in many languages that have a developed "tonal system" the prosodic multimember constituency of a syllable nucleus is not expressed through length but exclusively through change of pitch within the syllable nucleus itself. It may even be that in a language of this type both kinds of phonetic realization of "multimember constituency" exist side by side (p. 177)

Three (or even more!) distinctive degrees of quantity for the syllable nuclei are also indicated for some other languages, but not rightly so. In most of these cases quantity was confused with tone movement. (p. 180)

Further, we have already noted that length is not the only possible phonetic expression of prosodic gemination (presence of two morae) and that in certain languages the number of morae in a syllable nucleus is not expressed by length but by change of pitch within the nucleus. (p. 184)

However, this line of reasoning has not been commonly entertained in linguistic literature. A typical approach to the concept of quantity is to assume that its phonetic reflection is found in the acoustic duration alone. That quantity can be expressed by phonetic means other than duration has received attention in the studies of Estonian quantity (Fox & Lehiste 1987, 1989).

An informal test to some native Japanese listeners has indicated that in a pair like [obásáñ] 'aunt, middle aged woman' vs. [obáasan] 'grandmother, old woman', the role played by pitch change may be more crucial than the absolute duration of [a]. A further experiment in Japanese is in preparation to test which is the crucial cue for such pairs as those listed above.

CONCLUSION

This paper has suggested looking at both temporal and tonal dimensions in searching for the phonetic reality of the mora. Based on the production and perception data in Japanese, it has been pointed out that i) the acoustic duration alone is inadequate to capture the phonetic realization of the mora since a vowel of the same duration can be heard as either one or two moras depending on the F_0 movement it accompanies, ii) in the phonological dimension, a pair of words contrasting in segment duration, and typically in vowel duration, has a strong tendency to be accompanied by different pitch patterns as if to reinforce the contrast, and iii) because of this phonological relationship between temporal and tonal dimensions, there is restricted timing of F_0 . It should be timed at a mora boundary, for instance at V-C boundary in

a sequence like CVCV so that a single V will not be further divided into VV by F_0 movement. This kind of restriction in timing between F_0 and temporal dimension may prevent the use of F_0 to convey intonational meaning as such. Altogether, I think Trubetskoy 1969 was right in describing the concept of quantity not only by length but also by pitch change. It should prove fruitful for resolving the issue of the mora as well as for related prosodic phenomena to look at the interaction between the temporal and tonal events both at phonetic and phonological levels.

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REFERENCES

- Anderson, S.R. 1984. 'A metrical interpretation of some traditional claims about quantity and stress'. *Language sound structure*, eds. M. Aronoff & R. T. Oehrle, 83-106. Cambridge, Mass.: MIT Press.
- Beckman, M. 1982. 'Segment duration and the "mora" in Japanese'. *Journal of Phonetics* 39, 113-35.
- Bloch, B. 1950. 'Studies in colloquial Japanese IV: phonemics'. *Language* 26, 86-125.
- Bruce, G. 1981. 'Tonal and temporal interplay'. *Nordic Prosody II*, ed. T. Fretheim, 63-74. Trondheim: Tapir.
- Bruce, G. 1983. 'Accentuation and timing in Swedish'. *Folia Linguistica* 17, 221-38.
- Fox, R.A. & I. Lehiste. 1987. 'Discrimination of duration ratios by native English and Estonian listeners'. *Journal of Phonetics* 15, 349-63.
- Fox, R.A. & I. Lehiste. 1989. 'Discrimination of duration ratios in bisyllabic tokens by native English and Estonian listeners'. *Journal of Phonetics* 17, 167-74.
- Fujisaki, H. 1983. 'Dynamic characteristics of voice fundamental frequency in speech and singing'. *The production of speech*, ed. P. MacNeilage, 39-55. New York: Springer.
- Gårding, E. 1983. 'A generative model of intonation'. *Prosody: models and Measurements*, eds. A. Cutler & R. Ladd, 11-25. Heidelberg: Springer.
- Han, M.S. 1962. 'The feature of duration in Japanese'. *Onsei no kenkyuu* 10, 65-80.

- Hockett, C. 1955. *A manual of phonology*. Bloomington: Indiana University Publications in Anthropology and Linguistics.
- Jakobson, R. 1931. 'Die Betonung und ihre Rolle in der Wort- und Syntagmaphonologie'. *Selected Writings 1*, 117-36. The Hague: Mouton.
- Kawakami, S. 1977. *Nihongo onsei gaisetsu*. Tokyo: Oohuusha.
- Kindaich, H., D. Hayashi & T. Sibata, eds. 1988. *An encyclopaedia of the Japanese language*. Tokyo: Taishuukan.
- Klatt, D. H. 1975. 'Vowel lengthening is syntactically determined in a connected discourse'. *Journal of Phonetics* 3, 129-40.
- Ladefoged, P. 1975. *A Course in phonetics*. New York: Harcourt Brace Jovanovich.
- Lehiste, I. 1970. *Suprasegmentals*. Cambridge, Mass.: M.I.T. Press.
- Lindau, M. 1986. 'Testing a model of intonation in a tone language'. *Journal of the Acoustic Society of America* 80:3, 757-64.
- Martin, S.E. 1954. *Essential Japanese*. Rutland, Vt.: Tuttle.
- Mase, H. 1973. 'A study of the role of syllable and mora for the tonal manifestation in West Greenlandic'. *Annual Report of the Institute of Phonetics* 7, 1-98. University of Copenhagen.
- McGovern, W. 1953. *Colloquial Japanese*. London: Kegan Paul, Trench & Trubner.
- Nagano-Madsen, Y. 1987. 'Effects of tempo and tonal context on fundamental frequency contours in Japanese'. *Working Papers* 31, 103-16. Dept. of Linguistics, Lund University.
- Nagano-Madsen, Y. 1988. 'Phonetic reality of the mora in Eskimo'. *Working Papers* 34, 79-82. Dept. of Linguistics, Lund University.
- Nagano-Madsen, Y. & L. Eriksson. 1989. 'The location of F₀ turning point as a cue to mora boundary'. *Quarterly Progress And Status Report* 1, 41-45. Royal Institute of Technology, Stockholm.
- Pierrehumbert, J. 1980. *The phonology and phonetics of English intonation*. Ph.D. dissertation, Massachusetts Institute of Technology.
- Port, R.F., S. Al-Ani & S. Maeda. 1980. 'A temporal compensation and universal phonetics'. *Phonetica* 37, 235-52.
- Port, R.F., J. Dalby & M. O'Dell. 1987. 'Evidence for mora timing in Japanese'. *Journal of the Acoustical Society of America* 81, 1574-85.
- Rischel, J. 1974. *Topics in West Greenlandic phonology*. Copenhagen: Akademisk Forlag.
- Sugito, M. 1980. 'Akusento, intoneeshon no hikaku'. *Nichi-ei hikakukooza*, ed. T. Kunihiro, 107-83. Tokyo: Taishuukan.

- Trubetskoy, N.S. 1969. *Principles of phonology*. Translated by C.A.M. Baltaxe. University of California Press.
- Vance, T.J. 1987. *An introduction to Japanese phonology*. Albany: State University of New York Press.
- Young, J. & Nakajima K. [1967] 1981. *Learn Japanese*. Honolulu: University Press of Hawaii.