Weak elements make strong predictions: Evidence for gradient input features from Sino-Japanese compound accent

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The problem: Pitch-accent behaviour of two-member Sino-Japanese compounds looks semi-regular at best.

Morphemes show gradient accenting tendencies in a dataset of 1350 compounds.

M_1 accent-friendly	M_1 accent-resisting
hon 本 'this; 'main'; 'book' □□□□□□□□□□□□□□□□□□□□□□□□ 15/24	*sin* 新 'new' □□□□□□□□□□□□□□□□ 3/16
hón-poo 本法 'this law'	*sin-poo* 新法 'new law'
Contrary behaviour	
hon-ryuu 本流 'main-stream'	*sín-pei* 新兵 'new recruit'

Figure 1: (accented compounds shaded blue)

In these prosodically identical ((H)(H)) and morphologically minimal pairs above, with contrasting accentuation shown by shading, accent cannot be determined by E_1 alone or E_2 alone: *hon* 'main', *hoo*[1] 'law' and *sin* 'new' all variably affect accenting.

[1] /h/ surfacing as [*p*] is predictable and is orthogonal to this analysis.

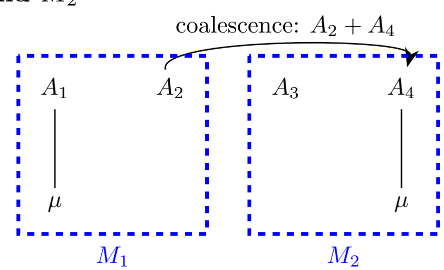
A Gradient Symbolic Computation account of semi-regular patterns

This framework (Smolensky and Goldrick, 2016) allows *partially-activated* input features. When two accent features coalesce in the output, their effective input activation is the sum of the two activations. This allows *accenting propensities* to be expressed by *input activations*. (See also Rosen (2016, 2018) for GSC accounts of gradient behaviour in native Japanese compound accent and Japanese rendaku voicing.)

Gradient features derive gradient behaviour

hon	sin	hei	hoo	ryuu
0_L 0.307_A 0.144_R	0_L 0.191_A 0_R	0.275_L 0_A 0_R	0.141_L 0_A 0_R	0_L 0_A 0_R
L = floating left A = anchored R = floating right				

Accent is determined by combined accenting tendencies of M_1 and M_2



Constraints - strongly weighted and not violated by optimal candidates

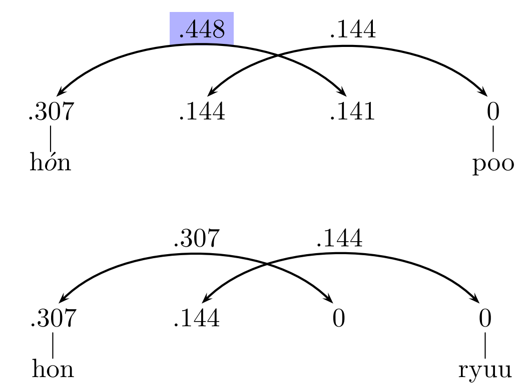
- An accent in the output must have a non-floating correspondent in the input. (Dep-Path-Accent)
- A floating feature can coalesce with an anchored feature on an adjacent but not the same morpheme. (strict Linearity in the domain of the morpheme)
- An anchored feature cannot coalesce with another anchored feature. That is, an accent feature with a path to a mora in the output cannot have more than one path to a mora in the input. (PathIntegrity)
- For simplicity, we only show candidates that respect strongly-weighted constraints requiring the leftmost syllable to be footed (InitFt) and disallowing a Foot to span a morpheme boundary except in the case of a minimal word of two light syllables such as 和紙 *wa-si* 'Japanese paper'.

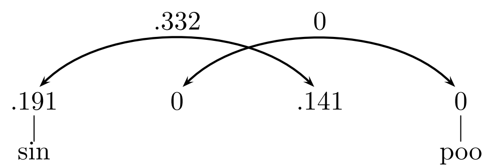
Constraints - less strongly weighted and potentially violated by optimal candidates

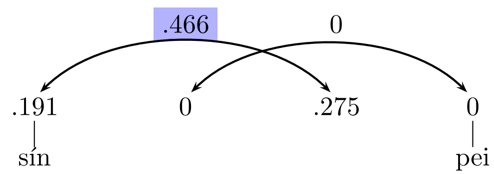
- Max with weight w_M rewards an input with activation a_i that surfaces, with positive Harmony $w_M \cdot a_i$.
- Dep with weight w_D costs negative Harmony to the amount of the deficit between full output activation and input activation, times the weight of the constraint: $w_D \cdot (1 - a_i)$.
- Rightmost (Ito and Mester, 2016, henceforth I&M): "*Ft' ...Ft...$]_\omega$ Violated by any foot following the head foot within the prosodic word."
- InitialFoot (I&M): "A prosodic word begins with a foot (Ito and Mester 1992:31, McCarthy and Prince 1993:81). "Violated by any prosodic word whose left edge is aligned not with the left edge of a foot, but of an unfooted syllable."
- NonfinalityFoot (I&M): "*Ft'$]_\omega$ Violated by any head foot that is final in its PrWd (Prince and Smolensky 1993(2004):45)"– final" in the sense that the right edge of Ft' coincides with the right edge of PrWd."
- Parse-σ (I&M) "All syllables are parsed into feet (Prince and Smolensky 1993(2004):62). Violated by unfooted syllables."
- WordAccent (Itô and Mester 2016): "A prosodic word contains a prominence peak. Violated by prosodic words not having a prominence peak (peak=primary stress or pitch accent, in Japanese: High*⌒Low))." Here, instead, we award positive Harmony to candidates that respect this constraint.
- We also propose a constraint Prejunctural that rewards candidates that place an accent before the compound juncture. This constraint recognizes the tendency of Japanese compounds of this prosodic length to place an accent before the compound juncture. (See Kawahara (2015)).
- Weighted Max and Dep and prosodic constraints determine am epiphenomenal threshold of activation that an (aggregate) input must surpass in order to surface.
- The winning candidate has the highest Harmony value H.

We posit underlying accent features with gradient activation that are anchored to moras or float at the left and/or right morpheme edge. Arcs below indicate coalescence of a floating feature with an anchored feature.

Coalescence of gradient features creates summed activations (threshold 0.368)







Tableaux for the four compounds of contrasting accent in Table 1

Apart from the effects of input activations, the net effects of the last 4 prosodic constraints give accent on M_1 a Harmony advantage of 0.027 over accent on M_2. ($w_{Prejunc} - w_{Parse} = -0.063$ for M_1. $w_{NonFin} = -0.090$ for M_2)

hon+hoo	Max +1.098	Dep −0.902	Rmost −0.183	Parse −0.181	Prjnc +0.118	WdAcc +0.098	NonFin −0.090	H
☞ **(hón)-poo** $0.307_A + 0.141_L$	0.492[2]	−0.498		−0.181	0.118	0.098		0.029
(hón)-(poo) $0.307_A + 0.141_L$	0.492	−0.498	−0.183		0.118	0.098		0.027
(hon)-(póo) $0.144_R + 0_A$	0.158	−0.772				0.098	−0.090	−0.606
(hon)-(poo)								0

Compound *sin-poo* 'new-law' does not accent, in contrast to *hón-poo* 'this-law', because of lower anchored input activation on *sin* 'new'.

sin+hoo	Max +1.098	Dep −0.902	WdAcc −0.183	Rmost −0.181	Parse +0.118	Prjnc +0.098	NonFin −0.090	H
(sín)-poo $0.191_A + 0.141_L$	0.365	−0.603		−0.181	0.118	0.098		−0.203
(sín)-(poo) $0.191_A + 0.141_L$	0.365	−0.603	−0.183		0.118	0.098		−0.205
(sin)-(póo) $0_R + 0_A$	0	−0.902				0.098	−0.090	−0.894
☞ **(sin)-(poo)**								0

Compound *hon-ryuu* 'main-stream' does not accent, in contrast to *hón-poo* 'this-law', because of lack of input activation on *ryuu* 'flow; et al'.

hon+ryuu	Max +1.098	Dep −0.902	Rmost −0.183	Parse −0.181	Prjnc +0.118	WdAcc +0.098	NonFin −0.026	H
(hón)-ryuu $0.307_A + 0_L$	0.337	−0.625		−0.181	0.118	0.098		−0.253
(hón)-(ryuu) $0.307_A + 0_L$	0.337	−0.625	−0.183		0.118	0.098		−0.255
(hon)-(ryúu) $0.144_R\ 0_A$	0.158	−0.772				0.098	−0.026	−0.606
☞ **(hon)-(ryuu)**								0

Compound *sín-pei* 'new-recruit' does accent, in contrast to *sin-poo* 'new-law', because of higher left floating input activation on *hei* 'soldier'.

sin+hei	Max +1.098	Dep −0.902	Rmost −0.183	Parse −0.181	Prjnc +0.118	WdAcc +0.098	NonFin −0.090	H
☞ **(sín)-pei** $0.191_A + 0.275_L$	0.512	−0.482		−0.181	0.118	0.098		0.065
(sín)-(pei) $0.191_A + 0.275_L$	0.512	−0.482	−0.183		0.118	0.098		0.063
(sin)-(péi) $0_R + 0_A$	0	−0.902				0.098	−0.090	−0.894
(sin)-(pei)								0

Change in accentuation when morpheme order switches: not explainable in OT or HG, with lexically-indexed constraints

字数 *zi-súu* '# of written characters' ACCENTED (LH)	数字 *suu-zi* 'numeral' UNACCENTED (HL)
波長 *ha-tyoo* 'wavelength' UNACCENTED (LH)	長波 *tyóo-ha* 'long-wave' ACCENTED (HL)

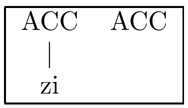
Prosody cannot explain this contrast. (Opposite correlation between prosody in accent between the two pairs.)

HG (e.g. Pater (2009)) or OT (Prince and Smolensky, 1993) with lexically-indexed constraints[3] (Pater, 2000, inter alia) is insensitive to switching the morpheme order, *unless* edge-aligned floating features and coalescence occur, but this then leads to problems:

[3]See Round (2017) for an argument against indexing constraints to morphs rather than phonological elements.

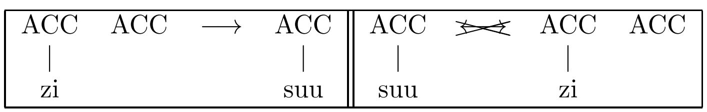
- In OT or HG, for accented *zi-súu* 'number of written characters', there must be some underlying accent feature somewhere since no accent surfaces in prosodically identical *ha-tyoo* 'wavelength'.
- Why doesn't it surface on *suu-zi* 'numeral'?
- Any ranking or weighting of MAX-ACC_{zi}, MAX-ACC_{suu}, $^*\text{ACC}_{zi}$ and $^*\text{ACC}_{suu}$ that derives accented *zi-súu* should predict *suu-zi* 'company' to also be accented.

The only possible resort:

- Coalescence of anchored and floating features, as in the GSC account, to distinguish the left from the right edge of a morpheme.
- Suppose there is a floating accent feature on the right edge of *zi*:
- 

- If there is the same kind of Path Integrity constraint proposed above that prevents an anchored feature from migrating to coalesce with another anchored feature, that right floating feature on *zi* can coalesce onto *suu* to cause accenting with the ranking below on *suu*, but not vice versa in *suu-zi*, where no coalescence can occur.

  $^*\text{ACC}_{zi} \gg \text{MAX-ACC}_{zi} \gg {}^*\text{ACC}_{suu} \gg \text{MAX-ACC}_{suu}$

- 

If constraints are weighted rather than categorically ranked:

$^*\text{ACC}_{zi} > \text{MAX-ACC}_{zi}$ ia needed to prevent accent on *zi*.

$^*\text{ACC}_{suu} > \text{MAX-ACC}_{suu}$ is needed to prevent *suu* from accenting in *suu-zi*.

But now, having no leftward floating accent feature on *zi* prevents it from triggering accent on an M_1 when *zi* is an M_2:

zyúu-zi ('ten' + 'character') 'cross', (accented), requires the ranking $\text{MAX-ACC}_{zyuu} \gg {}^*\text{ACC}_{zyuu}$ with an underlying accent on *zyuu* since *zi*, with no left floating feature, is unable to help accent surface on it. If constraints are weighted, it must be that $\text{MAX-ACC}_{zyuu} > {}^*\text{ACC}_{zyuu}$. $^*\text{ACC}_{zi} > \text{MAX-ACC}_{zi}$, will, as before, prevent accenting on *zi*. The constraints on *zyuu* and *zi* cannot interact if there is no possible coalescence.

It then should become impossible for a compound with *zyuu* as M_1 to be unaccented, since whatever the input form or indexed constraint ranking of M_2, the compounds should surface with accent on *zyuu*. This is contradicted by examples like *zyuu-moku* 'all eyes' (unaccented).

GSC, which allows gradient activations, is able to derive all four compounds, since different activations can occur on different accent features: floating at L and/or R edges (shown by L and R subscripts) and μ-anchored (A subscript) :

Learned input accent activations for *suu*, *zi*, *zyuu* and *moku*			
0.092 0.156	0.317 |	0.359 0.261 |	0
zi	*suu*	*zyuu*	*moku*

- *zyuu* accents before *zi* but *suu* doesn't, because .359 > .317.
- *zyuu-moku* doesn't accent because *moku* has no activation to add to the activation on *zyuu* to bring it above the threshold.

zi+suu	MAX +1.098	DEP −0.902	RMOST −0.183	PARSE −0.181	PRJNC +0.118	WDACC +0.098	NONFIN −0.090	H
(zí)-suu $0_A + 0_L$	0	−0.902		−0.181	0.118	0.098		−0.867
(zí)-(suu) $0_A + 0_L$	0	−0.902	−0.183		0.118	0.098		−0.869
☞ **(zi)-(súu)** $0.156_R + 0.317_A$	0.519	−0.475				0.098	−0.090	0.052
(zi)-(suu)								0

Unlike the case of OT or HG in which input representations must have discrete values of 0 or 1, gradient values in GSC allow a weak floating accent activation at the left edge of *zi*, which allows it to accent variably. OT/HG needs to prevent any floating feature on the left of *zi* so that *suu-zi* doesn't accent.

suu+zi	MAX +1.098	DEP −0.902	RMOST −0.183	PARSE −0.181	PRJNC +0.118	WDACC +0.098	NONFIN −0.090	H
(súu)-zi $0.317_A + 0.092_L$	0.449	−0.533		−0.181	0.118	0.098		−0.049
(súu)-(zi) $0.397_A + 0.092_L$	0.449	−0.533	−0.183		0.118	0.098		−0.051
(suu)-(zí) $0_R + 0_A$	0	−0.902				0.098	−0.090	−0.894
☞ **(suu)-(zi)**								0

A higher anchored activation on *zyuu* allows it to accent with *zi*.

zyuu+zi	MAX +1.098	DEP −0.902	RMOST −0.183	PARSE −0.181	PRJNC +0.118	WDACC +0.098	NONFIN −0.090	H
☞ **(zyúu)-zi** $0.359_A + 0.092_L$	0.495	−0.495		−0.181	0.118	0.098		0.035
(zyúu)-(zi) $0.359_A + 0.092_L$	0.495	−0.495	−0.183		0.118	0.098		0.033
(zyuu)-(zí) $0.261_R + 0_A$	0.287	−0.667				0.098	−0.090	−0.372
(zyuu)-(zi)								0

But not with *moku*, which has no left floating activation.

zyuu+moku	MAX +1.098	DEP −0.902	WDACC −0.183	PARSE −0.181	PRJNC +0.118	RMOST +0.098	NONFIN −0.090	H
(zyúu)-moku $0.359_A + 0_L$	0.395	−0.578		−0.181	0.118	0.098		−0.149
(zyúu)-(moku) $0.359_A + 0_L$	0.395	−0.578	−0.183		0.118	0.098		−0.151
(zyuu)-(móku) $0.261_R + 0_A$	0.287	−0.667				0.098	−0.090	−0.372
☞ **(zyuu)-(moku)**								0

Learning Algorithm for constraint weights and accent activations

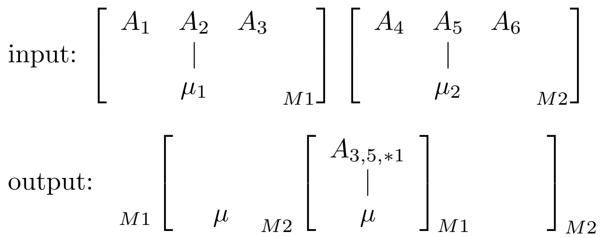
- Initialize all activations at 0.5 and constraint weights at 0 except for MAX and DEP which start at 1.
- On each iteration, go through all the compounds in the database.
- For each compound, calculate the Harmony for M_1 accent, M_2 accent and no accent according to the input activations and constraint weights.
- Following I&M, we consider candidates that do not parse a second heavy syllable.
- If the correct accent pattern has the highest Harmony by a margin of at least 0.01, continue.
- Otherwise, adjust the constraint weights and activations by a decaying stepsize (that starts at 0.03) in the direction that favours the correct output. Keep positive and negative constraint values on the correct side of zero and activations at or above zero.
- After each iteration, decay the stepsize by a factor of 0.96
- On every second iteration, decay the value of any activation that has not needed to be adjusted in those iterations. This is to bring values down from 0.5 to zero that do not need to have a nonzero value.
- Repeat until all compounds in the database are learned correctly.

Resolving some issues

1. What prevents a floating accent feature on the left from associating to a morpheme on its right, and vice versa, if the other accent features do not surface?
2. Are morphemes that form a compound word ordered in the input if morpheme order makes a difference, as we saw above? This is arguably a different matter than affix ordering and cannot be handled in any obvious way through ordering of affixes, as in de Lacy (1999).

- Given the fact that ordering of the constituents in the input makes a difference, both semantically and with respect to accent, we take constituents of a compound to be ordered in the input. We still do not lose the ability to rule out coalescence of features from the same morpheme through strict linearity if we make the morpheme the domain of a strong LINEARITY constraint and the prosodic word the domain of a weaker LINEARITY constraint.
- The following constraint, highly weighted, would prevent A_1 from coalescing on morpheme 2 below: "If A_i and A'_i stand in correspondence, and A_i is left-aligned with morpheme M_j in the input, then A'_i is left-aligned with morpheme M_j in the output." The same with right alignment.
- If A_1, which is floating to the left of another accent on M_1, associates with the second morpheme, it will no longer be left-aligned with morpheme 1 if we consider both the accentual tier and moraic tier at once and measure alignment there.

- Whether or not A_4 is there in the input does not matter.



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