Hardening alternation in the Mitsukaido dialect of Japanese*

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1. Introduction

The Mitsukaido dialect of Japanese, spoken in the southwestern part of Ibaraki prefecture, is a dialect displaying mixed grammatical properties. It exhibits both Tohoku dialect properties, such as intervocalic voicing and consonant devoicing, and southern Kanto dialect properties, such as lack of prenasal consonants. The mixed grammatical properties also found in morphosyntax, having the dative/allative case particle *–sa* like Tohoku dialects and lacking productive anticausative voice like southern Kanto dialects. Due to this mixed nature, the Mitsukaido dialect is referred to as *Kanto no Tohoku-hogen* 'Tohoku dialect spoken in Kanto area'. The phenomenon I analyze in this paper is the hardening alternation exemplified in (1), a phonological alternation derived from the mixed nature of this dialect.

(1) Hardening alternations

s--ts alternations: **s**ɯkᵢkire: 'taste' – sewa**ts**ɯᵢki 'obliging', **ʃ**ᵢkage 'device' – bane**tʃ**ᵢkage 'spring-powered device', **ʃ**ᵢkipɯᵢtoN 'mattress' – ʃᵢita**tʃ**ᵢki 'a seat of plastic'

h--p alternations: **ɸ**ɯᵢtoN 'bedclothes' -- dza**p**ɯᵢtoN 'floor cushion', **ɸ**ɯᵢsogu 'lack' -- ne**p**ɯᵢsogu 'lack of sleep', **ç**ᵢikari 'light' -- ena**p**ᵢikari 'lightning', **ç**ᵢikaeru 'refrain' -- kae**p**ᵢikae 'refrain from buying', **ɸ**ɯᵢkuro 'bag' -- e**p**ɯᵢkuro 'stomach'

The hardening is not an independent phonological process, but a result from the opaque interaction among four phonological processes, namely, sequential voicing (voicing initial obstruent in the second element of compound, known as Rendaku), consonant devoicing (devoicing of C_1 accompanying V_1 devoicing in the environment /CV(N)$C_1V_1C_2V_2$/ where C_1 is /z/ or /b/, V_1 is a high vowel, C_2 is a voiceless obstruent), continuancy neutralization of voiced sibilants before high vowels and debuccalization of /p/ (p→h). The hardening occurs when the environments of these processes overlap. In the hardening alternation, consonant devoicing, a phonological process found also in Tohoku dialects, obscures the effects of sequential voicing and p→h. In terms of traditional generative phonology, consonant devoicing counterfeeds sequential voicing and debuccalization of /p/ and counterbleeds continuancy neutralization.

The classic form of Optimality Theory (Prince & Smolensky 1993) cannot account for this multiple opaque interaction. The aim of this paper is to provide a weak parallelist solution for the opaque interaction yielding hardening alternation. In order to account for the hardening alternation, I

* The data used in this paper is based on my field research in Mitsukaido city (the city was integrated into Joso city in 2006) conducted from 1994 to 2007. I am grateful to the Mitsukaido people who offered me a lot of information on the Mitsukaido dialect, especially to Mr. Nisaku Otaki, who showed extraordinary patience with my lengthy research. I have benefited from discussions with Daniela Caluianu. All errors and shortcomings are my own.

employ Stratal OT (Kiparsky 2000), a weak parallelist OT, as a framework, and posit two distinct constraint rankings, a lexical constraint ranking and a postlexical constraint ranking.

The structure of this paper is as follows: Section 2 introduces the basic properties of the MD, including the sketch of the four phonological processes relevant for the hardening alternations. The difficulty encountered in explaining the hardening alternations within the classic OT architecture is illustrated in Section 3. A Stratal OT solution is proposed in Section 4. In Section 5, I consider the availability of the other OT extensions for phonological opacity to the opaque interaction found in the hardening. Section 6 concludes the discussion.

I limit the scope of this paper to the interaction yielding the hardening alternation. There is another phonological process related to the hardening alternation, intervocalic voicing of stop consonants. This phonological process obscures the condition for sequential voicing and it can be regarded as a process related to the hardening alternation. However, in order to concentrate the analysis of hardening alternation itself, I do not deal with intervocalic voicing at length and will refer it only when it is relevant for the discussion.

2. Basic properties

This section introduces the basic properties of the Mitsukaido dialect phonology. I provide the inventory of consonant phonemes and of the allophonic "rules" (I use this term as a pretheoretical one for the purpose of presentational convenience without any theoretical intention) relevant for the discussion in 2.1. Phonological and morphological conditions of the four phonological processes, of which interaction result in the hardening alternation, are provided in 2.2.

2.1. Consonant inventory

Despite of its commonality in phonological processes with Tohoku dialects, the inventory of consonant phonemes of the Mitsukaido dialect is basically same as the Tokyo dialect. The inventories of consonant phonemes in the Mitsukaido Tokyo, and Tohoku dialects are illustrated in (2).[1] This dialect lacks prenasal stops (˜b, ˜d, ˜g), which characterize the Tohoku dialect sound systems, not only as phonemes but also as allophones.[2] This property is a source of opacity in the interaction of labial consonant debuccalization (p-->h) and consonant devoicing. I will return to this point in 2.2.

[1] I omit the archiphonemes /N/ (moraic nasal) and /Q/ (non-nasal moraic consonant) because of the irrelevance for the discussion.

[2] Some researchers assume that voiced--voiceless opposition for Tohoku dialects and the prenasality of voiced consonant is derived through prenasalization (Shibata 1954). In this article, I do not adopt this analysis and I assume that the prenasality as an underlying property. The assumption of underlying prenasality is accommodated with the following diachronic fact: prenasalization has never happened as a diachronic process, while the existence of diachronic de-prenasalization is confirmed by the literature.

(2) a. Consonant inventory of the Mitsukaido dialect (Sasaki 2004a)

/p, b, t, d, k, g, s, z, h, r, m, n, w, j/

b. Consonant inventory of the Tokyo dialect (Shibatani 1990)

/p, b, t, d, k, g, s, z, h, r, m, n, w, j/

c. Consonant inventory of the Tohoku dialect[3]

/p, ˜b, t, ˜d, k, ˜g, s, ˜z, h, r, m, n, w, j/

The allophonic rules that determine the phonetic realization of obstruent phonemes are listed in (3). These rules are found also in Tokyo dialect, but the phonetic details are not completely the same.

(3) Relevant allophonic processes

Affrication: t-->ts, tʃ/__[+high] (i.e., high vowels i and u, and glide j)

Palatalization: s, t --> ʃ, tʃ/__[+high, -back] (i.e., high vowel i and glide j)

h-->ç/__[+high]

h-->ɸ～x/__u (friction caused by labial striction is very weak)

/g/-->[ŋ] except for word-initial position; /g/ is realized as [g] in the word-initial position.

Phonemic resemblance extends to vowel inventory: both southern Kanto dialects, including the Tokyo dialect, and the Mitsukaido dialect have five vowel phonemes /a, i, u, e, o/, although /e/ and /i/ in the Mitsukaido dialect correspond to /i/[4] and /ju/ in southern Kanto dialects, respectively (see Sasaki 2003 for detail on the correspondence). Phonemic resemblance stops in at the prosodeme. The Mitsukaido dialect is classified as an accentless dialect, while southern Kanto dialects have distinctive accentuation.

2.2. Relevant processes

The hardening alternation is a result of the interaction of four phonological processes, sequential voicing, continuancy neutralization, debuccalization of /p/ (p-->h) and consonant devoicing. Conditions and effects of each process are provided from 2.2.1 to 2.2.4. In 2.2.5, the interaction of four phonological processes is illustrated.

2.2.1. Sequential voicing

Sequential voicing, also known as Rendaku, is a well-studied morphophonological process both in traditional grammar and generative grammar. This process affects the initial obstruent of the second

[3] Inoue (1968) advocates three way opposition system for the Tohoku dialects, including /p, b, ˜b, t, d, ˜d, k, g, ˜g/. The existence of voiced (non-prenasal) stop is motivated by the existence of exceptional voiceless stops, most of which are derived from the phonological processes other than intervocalic voicing and morphological peculiarity.

[4] The /i/ in southern Kanto dialects corresponds to the /i/ in the Mitsukaido dialect only when it has no onset, e.g., /iki/ ‘breath’ in southern Kanto dialects corresponds to /eki/ in the Mitsukaido dialect but the word standing for ‘wood’ is /ki/ in both dialects.

element of a compound. The initial voiceless obstruent turns into a voiced one by sequential voicing. The effect of sequential voicing in this dialect is the same as in Standard Japanese, namely, the initial /p/ ([h]), /t/ and /k/ become [b], [d] and [ŋ], respectively ([ŋ] is an allophone of /g/ in non-word-initial position). See the examples in (4).

(4) Sequential voicing

/p/-->[b] tebadagi /te-pataki/ 'handclap', Nmeboʃi /Nme-posi/ 'pickled ume', bagabanaʃi /baka-panasi/ 'talking nonsense', egebana /eke-pana/ 'flower arrangement', herabɯna /pera-puna/ 'a kind of crucian'

/t/-->[d] hondana /hoN-tana/[5] 'bookshelf', mizɯdeppo: /mizu-teppo:/[6] 'water pistol'

/s/-->[z] teʒagɯ /te-sjaku/ 'pouring one's own sake', odamaʒakɯ̥ʃi /otama-sjakusi/ 'wooden ladle', iwaezage /iwae-sake/ 'sake for celebration', aozora /ao-sora/ 'blue sky', koʒima /ko-sima/ 'small island', ɕi̥torizɯmo: /pitori-sumo:/ 'fight windmills'

/k/-->[ŋ] neŋɯse (*nekɯ̥se) /ne-kuse/[7] 'disheveled hair', agaŋire /aka-kire/ 'crack in the skin', teŋama /te-kama/ 'small sickle', sagɯraŋami /sakura-kami/ 'tissue', mizɯŋɯsɯri /mizu-kusuri/ 'liquid medicine', hoʃiŋagi /posi-kaki/ 'dried persimmon'

However, the condition of sequential voicing in this dialect differs from that of Standard Japanese. When the second element of a compound has a voiced obstruent (b, d, g, z) in non-initial syllable, sequential voicing is blocked. This condition is known as Lyman's Law (Lyman 1894) and has been analyzed as a case of obligatory contour principle (Leben 1973, Goldsmith 1976) in non-linear phonology (Ito & Mester 1986). In SJ, the condition is visible in both the underlying representation and the surface phonetic representation except for velar obstruent, of which voiced member /g/ is realized as [ŋ] in non-initial position. Lyman's Law is a relevant condition also in the Mitsukaido dialect but it is always true only in the underlying representation. Due to the effect of other processes, i.e., intervocalic voicing (yielding [d(z)] and [g] from /t/ and /k/ in intervocalic position), consonant devoicing and allophonic rule yielding velar nasal, the condition sometimes becomes covert.

(5) a. Lyman's law (overt)

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[5] The voicing of /t/, the initial obstruent of the second element of *hondana*, cannot be due to intervocalic voicing because /t/ does not stand in the intervocalic position.

[6] The /t/ in /mizu-teppo:/ is in a intervocalic position. In this position, /t/ is a target of intervocalic voicing and also a trigger of consonant devoicing at the same time. In such a situation, consonant devoicing has priority over intervocalic voicing. The example *mitsu̥kage* /mizu-kake/, where sequential voicing is not applicable because of the compound consists of object-predicate relationship, illustrates the priority of consonant devoicing. In the case of *mizudeppo:* /mizu-teppo:/, voicing rather than devoicing applies to /t/. This voicing could not be due to intervocalic voicing because consonant devoicing might block it. The cause of voicing must be sequential voicing.

[7] The form [neŋɯse] undergoing sequential voicing exempts from consonant devoicing from the following voiceless obstruent [s]. This is due to the nasality of [ŋ]. The non-nasal voiced consonants derived from the application of sequential voicing are a target of consonant devoicing.

[-...d...] blocks sequential voicing: motʃ̬ihada (*motʃibada) /moti-pada/ ‘soft fair velvety skin’

[-...b...] blocks sequential voicing: kagesoba (*kagezoba) /kake-soba/ ‘buckwheat noodles in soup’

[-...z...] blocks sequential voicing: warɯhɯzage (*warɯbɯzage) /waru-puzake/ ‘prank’, kosazi (*kozazi) /ko-sazi/ ‘small spoon’, aosɯzi (*aozɯzi) /ao-suzi/ ‘blue veins’

b. Lyman’s law (covert)

[-...p...] blocks sequential voicing: sagɯraɸɯ̬pɯ̬ki /sakura-pubuki/ ‘cherry blossom storm’, cf. sagɯraŋami /sakura-kami/ ‘tissue’

[-...ts...] blocks sequential voicing: bagaʃo:tʃ̬iki /baka-sjo:ziki/ ‘honest to a fault’, cf. bagabanaʃi /baka-panasi/ ‘talking nonsense’

[-...ŋ...] blocks sequential voicing: aŋoçiŋe (*aŋobiŋe) /ago-pige/ ‘beard’

[-...d...] does not block sequential voicing: denʃobado /deNsjo-pato/ ‘carrier pigeon’

[-...g...] does not block sequential voicing: iwaezage /iwae-sake/ ‘sake for celebration’

However, in most cases, the condition of blockage of sequential voicing is recoverable. For velar and labial consonants, the underlying specification of [voice] is easily inferred. As in SJ, [ŋ] is an allophone of /g/ in non-initial position. The blockage of sequential voicing by [ŋ] is expected from the phoneme-allophone correspondence. Non-geminate [p] in intervocalic position in native and Sino-Japanese stems (sequential voicing applies only for these lexical items) is a result of consonant devoicing of /b/. The underlying specification of [voice] is inferred from the grammatical knowledge with no difficulty. The situation is the same in the case of [g]. The [g] in intervocalic position results from intervocalic voicing applying to /k/. The intervocalic [g]’s underlying nonspecification of [voice] is inferred. On the other hand, the underlying specification of [voice] for coronal obstruents is indicated by the behavior of the segment in sequential voicing, except for /z/ before non-high vowels (in this environment, /z/ does not undergo a process obscuring the specification of [voice], i.e., consonant devoicing).

Sequential voicing is found not only in the compound vocabulary shared with SJ but in the folk vocabulary such as [iŋe:ʃi] /i-kaesi/ ‘cooperation-return’. This indicates that sequential voicing is an active morphophonological processes in the grammar of this dialect.

Sequential voicing interacts with other phonological processes as mentioned above. Sequential voicing feeds continuancy neutralization. Sequential voicing bleeds debuccalization of /p/ (p-->h). Consonant devoicing counterfeeds sequential voicing. These interactions are crucial for understanding the hardening alternation and their details are illustrated in the following subsections.

2.2.2. Continuancy neutralization

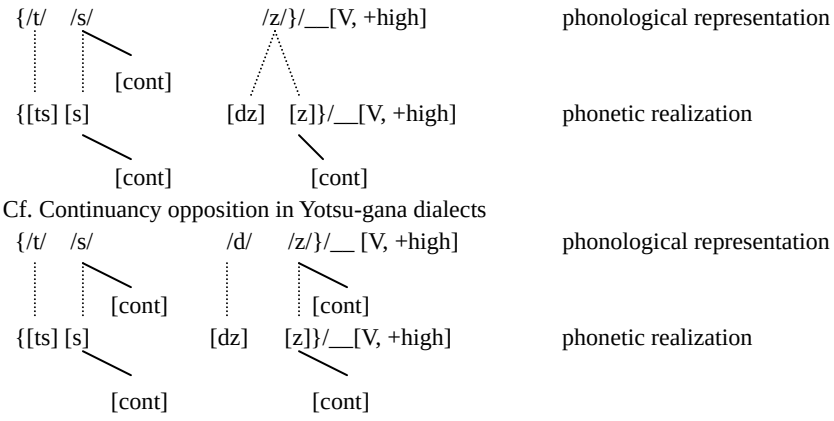
Japanese dialects are classified into four categories for the phonotactic restriction on continuancy of voiced coronals before [+high] segments (high vowels and glide j).

(6)	4-way distinction (Yotsu-gana):	/di,	zi,	du,	zu/
	3-way distinction (Mitsu-gana):	/	zi,	du,	zu/
	2-way distinction (Futatsu-gana):	/	zi,		zu/
	1-way distinction (Hitotsu-gana):	/	(˜)zI		/

Dialects with 4-way distinction are found in Kagoshima prefecture and Kochi prefecture. This type of distinction is the most conservative. 3-way distinction dialects are spoken in a part of Oita prefecture. This type of dialect lost the distinction of continuancy on voiced coronal obstruents before /i/ and maintains it before /u/. 1-way distinction dialects are found in Tohoku area and known as *Zuzu-ben*, where there is no continuancy distinction before high vowels and the distinction of /i/ and /u/ is neutralized after coronal consonants. The majority of dialects spoken in the remaining area display a 2-way distinction, where there is no continuancy distinction before high vowels and the distinction of /i/ and /u/ is maintained after coronal consonants unlike the 1-way distinction dialects. The Mitsukaido dialect is classified into this class, as well as Standard Japanese.

The continuancy opposition in Futatsu-gana dialects, including the Mitsukaido dialect, is illustrated in (7).

(7) Continuancy opposition in Futatsu-gana dialects



Before non-high vowels, the phonetic realization of /d/ is [d] wherever it stands. In the same environment, the phonetic realization of /z/ depends on the context. When it stands in the word-initial position or it follows homorganic nasal, /z/'s allophone is an affricate [dz]. Otherwise, it realizes as fricative [z]. Before high vowels, the distinction of /d/ and /z/ is neutralized. The stop consonant [d] never occurs before high vowels. The affricate [dz] and the fricative [z] occur before

high vowels. Their occurrence is predictable from the environment. When the preceding element is word boundary (#) or homorganic nasal, the affricate [dz] emerges. Otherwise, the fricative [z] occurs. The affricate [dz] and the fricative [z] are considered to be allophones of the same phoneme because the distribution of [dz] and [z] is complementary. I use the symbol /z/ for the voiced coronal obstruent phoneme not only in the environment before non-high vowels but also before high vowels due to their same appearance of allophones. But the feature [continuant] is assumed to be underspecified for the /z/ before high vowels, while the /z/ before non-high vowels is specified with [continuant]. The reason for the underspecification is two-fold, non-distinctness and interaction with other processes. In this position, the continuancy is not distinctive for voiced coronal obstruents as mentioned above, and the continuancy is predictable from its environment. From this non-distinctiveness and predictability, [continuant] for /z/ before high vowel is redundant and therefore it can be left unspecified. Phonological alternation also supports the underspecification of /z/ in this position. When consonant devoicing applies to the voiced coronal obstruent before high vowels, the resulting segment is [ts], not [s] (for the examples, see 2.2.4). The affricate [ts] is an allophone of /t/ before high vowels and /t/ is an unmarked member for [continuant] in the voiceless coronal obstruents (the marked member is /s/). These facts indicate the underspecification of [continuant] for /z/ before high vowels.

Behind the restriction of continuancy opposition, I assume the phonotactic constraint *[voice, cont, cor][high], incurring continuancy neutralization of voiced coronal obstruents before high vowels and glides. The effect of this constraint is visible when voicing processes apply to the voiceless coronal obstruents before high vowels. The examples in (8) and (9) illustrate the interaction between sequential voicing and continuancy neutralization. The data in (8) indicate that sequential voicing feeds continuancy neutralization, i.e., coronal obstruents lose their continuancy opposition when they undergo sequential voicing. Both /t/ and /s/ become [z] in the intervocalic position and, [dz] after homorganic nasal.

(8) Sequential voicing feeds continuancy neutralization

a. Intervocalic position: /t, s/-->[z]

t(-->d)-->z (ʒ): /tura/ [tsɯra] ‘face’, /baka-tura/ [bagazɯra] ‘stupid face’

s-->z (ʒ): /sima/ [ʃima] ‘island’, /ko-sima/, [koʒima] ‘small island’

b. After homorganic nasal: /t, s/-->[dz]

t(-->d)-->dz (dʒ): /tume-ru/ [tsɯmeru] ‘pack’, /kaN-tume/ [kandzɯme] ‘canned food’

s(-->z)-->dz (dʒ): /iQ-suN/ [issɯN] ‘1 sun’, /ni-suN/ [nisɯN] ‘2 sun’, /san-suN/ [sandzɯN] ‘3 sun’ (sun=3.03cm)

/siru/ [ʃirɯ] ‘soup’, /keNtiN-siru/ [kentʃindʒirɯ] ‘kenchin soup’

Intervocalic voicing, widespread in Tohoku dialects, also feeds continuancy neutralization. The data

in (9) illustrate this transparent interaction. The verbal root meaning ‘stand’ ends in a voiceless coronal stop, /tat-/. When it stands in a position exempting from intervocalic voicing, the root final consonant realized as [t] as shown in the past form [tatta]. On the other hand, when it stands in a position undergoing intervocalic voicing, it is realized as [d] as illustrated in the negative form [tadane][8]. When it stands in a position where the conditions for both intervocalic voicing and continuancy neutralization meet, i.e., the environment /...Vt+high vowel.../, /t/ is realized as [z], not [dz], undergoing both processes. The present form [tazɯ] illustrates this transparent interaction.

(9) Intervocalic voicing feeds continuancy neutralization
/tat-u/ [tazɯ] ‘stand-pres’
cf. /tat-a-ne/ [tadane] ‘do not stand’, /tat-ta/ [tatta] ‘stood’

Consonant devoicing interacts with continuancy neutralization opaquely. This opaque interaction constitutes a part of hardening alternation. For this interaction, see 2.2.4 and 2.2.5.

2.2.3. Debuccalization of /p/

The voiceless labial stop phoneme /p/ is realized as [h] through the application of debuccalization in the underived environment. This is illustrated in (10a). The /p/ as a part of geminate is exempt from this process as shown in (10b). This indicates that the target of debuccalization is restricted to the single occurrence of /p/. As illustrated in (10c), the application of sequential voicing to /p/ yields [b]. In terms of rule ordering, this can be captured by the ordering where sequential voicing bleeds (wipes out the condition of) debuccalization of /p/.

(10) a. Debuccalization (p-->h) in the underived environment
/pana/ [hana] ‘flower’, /pone [hone] ‘bone’
b. p-->h avoidance through gemination
koʃippone ‘hipbone’
c. Sequential voicing bleeds (wipes out the condition for) p-->h
/eke-hana/ [egebana] ‘flower arrangement’ (*egehana, *egeHana, *egepana) (H stands for voiced h)

There are exceptions for the debuccalization of /p/. The single occurrence of /p/ is not prohibited in loan words (11a) and onomatopeia (11b). This can be considered as a consequence of lexical stratification (Ito & Mester 1995). At this point, the situation concerning the debuccalization of /p/ in this dialect is same as Standard Japanese. The difference between Standard Japanese and the

8 Miyajima (1961) reports that for some speakers the negative form of ‘stand’ is [tazane]. This form is considered to be a result of analogy from the present form. The speaker I consulted uses the form without analogy.

Mitsukaido dialect is seen in the case of derived [p]. The [p]s derived through consonant devoicing are exempt from the application of p-->h, as shown in (11c). This indicates that consonant devoicing counterfeeds p-->h. As a result of this opaque interaction, some single (non-geminate) [p]s are found in native and Sino-Japanese vocabulary in this dialect.

(11) Non-application of p-->h
a. Loan words: paN ‘bread’
b. Onomatopeia: pɯ̥kɯpɯ̥ku, parapara
c. [p] derived through consonant devoicing: kapi̥kɯ̥se: /kabi-kuse:/ ‘musty’

2.2.4. Consonant devoicing

Consonant devoicing is a phonological process in which voiced obstruents /z/ and /b/ are devoiced and realized as [ts] and [p], respectively, through regressive assimilation of voicelessness from the voiceless obstruent in the following syllable, accompanying devoicing of high vowel between target (voiced obstruent) and trigger (voiceless obstruent), in the environment /...Ç$V_{[high]}$Ç̥V.../ (‘Ç’ stands for voiced obstruent and ‘Ç̥’ stands for voiceless obstruent). The word-initial /z/ and /b/ are exempt from this process. The output of this process is [...Ç̥$V̥_{[high]}$Ç̥V...]. This segmental sequence is the same one yielded by high vowel devoicing found in the majority of Japanese dialects including Standard Japanese (for the detail of high vowel devoicing, readers may refer to Tsuchida 2000 and Yoshida 2002, and the literature cited therein). The difference between high vowel devoicing and consonant devoicing lies in the underlying representation. Both of the obstruents following and preceding the high vowel in the input must be voiceless for high vowel devoicing, while the only following obstruent is required to be voiceless for consonant devoicing.

The occurrence of this process is limited inside the word. As shown in (12), consonant devoicing occurs in several types of derived environments. Consonant devoicing in compound formation is illustrated in (12a). In the examples in (12b), consonant devoicing occurs in derivational morphology of verbal root and suffix combinations. The examples in (12c) illustrate the consonant devoicing in inflectional morphology. Consonant devoicing is also found in underived environments as shown in (13). The derived nature of voicelessness of [ts] and [p] in (13) can be inferred from the interaction with another phonological process. The [ts] and [p] in (13) blocks sequential voicing like voiced obstruents as mentioned in (5b) above.

(12) Consonant devoicing in derived environment
a. Compounding
z-->ts (tʃ): atʃi̥tsɯ̥ke /azi-tuke/ ‘seasoning’, hatʃi̥saraʃi /hazi-sarasi/ ‘disgrace’, mitsɯ̥kage /mizu-kake/ ‘sprinkling water’
b-->p: kopɯ̥tʃa /kobu-tja/ ‘tea made of powdered kelp’, kapi̥kɯ̥se: /kabi-kuse:/ ‘musty’

b. Derivational morphology

Transitivity alternations

b-->p: kabɯrɯ /kabur-u/ ‘put something on the head (vt)’-- kapɯ̥sarɯ /kabusar-u/ ‘cover on the head (vi)’-- kapɯ̥serɯ /kabuse-ru/ ‘cover something on the head (vt)’, obɯɯ /obuw-u/ ‘carry a child on one’s back (vt)’-- opɯ̥sarɯ /obusar-u/ ‘be carried on someone’s back (vi)’, abirɯ /abi-ru/ ‘pour water over oneself (vt)’– apʲ̥serɯ /abise-ru/ ‘pour water on someone (ditransitive)’

z-->ts: hazɯrerɯ /hazure-ru/ ‘come off (vi)’-- hatsɯ̥sɯ /hazus-u/ ‘take off (vt)’

Desiderative formatoin

z-->ts: o:ʒirɯ /o:zi-ru/ ‘answer’ -- o:tʃ̥ite: /o:zi-te:/ ‘want to answer’

b-->p: abirɯ /abi-ru/ ‘pour water over oneself’—apʲ̥te: /abi-te:/ ‘want to pour water over oneself’

c. Inflectional morphology

z-->ts: kʲ̥tsɯ̥kane: /kizuk-a-ne/ ‘do not notice’-- kizɯeda /kizuk-i-ta/[9] ‘noticed’, hatʃ̥ikane: /pazik-a-ne:/ ‘do not snap’-- haʒi:da /hazik-i-ta/[10] ‘snapped’, toʒine: /tozi-ne:/ ‘do not close’—totʃ̥ita /tozi-ta/ ‘closed’

b-->p: napʲ̥kane: /nabik-a-ne:/ ‘do not wave’-- nabi:da /nabik-i-ta/ ‘waved’, abine: /abi-ne:/ ‘do not pour water over oneself’—apʲ̥ta /abi-ta/ ‘poured water over oneself’

(13) Consonant devoicing in the non-derived environment[11]

z-->ts: ʃo:tʃ̥iki /sjo:ziki/ ‘honest’, atʃisae /azisae/ ‘hydrangea’, watsɯ̥ka /wazuka/ ‘a few’

b-->p: kapɯ̥to /kabuto/ ‘helmet’, fɯpɯ̥ki /pubuki/ ‘snow storm’

Inside the word, the /...C̥V$_{[high]}$C̥V.../ sequence exempt from consonant devoicing is found in loan words and onomatopeia as shown in (14a-b). Intervocalic voicing instead of consonant devoicing occurs in onomatopoeia. The /...C̥V$_{[high]}$C̥V.../ sequence formed at the word-particle boundary and word boundary is also exempt from consonant devoicing. For the word-particle boundary, intervocalic voicing rather than consonant devoicing applies as illustrated in (14c). As shown in

[9] The form [kizɯeda] is derived through velar deletion, vowel lowering (lowering targeting /i/ without onset) and intervocalic voicing. Velar deletion removes the root-final /k/. As a result of this process, the stem-final /i/ loses its onset and the /i/ without onset becomes [e], undergoing vowel lowering (for detail of vowel lowering, see Sasaki 2003). The /t/ in the initial position of past tense suffix undergoes intervocalic voicing.

[10] The form [haʒi:da] is derived by the application of velar deletion of the root final consonant and intervocalic voicing of suffix-initial /t/. It does not undergo vowel lowering to the stem-final /i/ because the coalescence of the root final /i/ and the stem final /i/ wipes out the condition for vowel lowering, i.e., the stem-final /i/ integrated into the preceding /i/ acquires the onset, [ʒ], which is also an onset of the root-final /i/.

[11] The underlying voicing of voiceless obstruents derived from consonant devoicing in the non-derived environment is ascertained by the covert OCP effect, blocking of sequential voicing, illustrated in (5b) in 2.2.1.

(14d), no voicing alternations occur at the word boundary.

(14) Non-application of devoicing

a. Loan words: gibɯsɯ /gibusu/ ‘plaster cast (from Gips (German))’

b. Onomatopeia (cf. intervocalic voicing applies): bɯzɯbɯzɯ (*bɯzɯpɯ̥tsɯ, *bɯtsɯ̥pɯ̥tsɯ), bɯgɯbɯgɯ (*bɯgɯpɯ̥kɯ, *bɯkɯ̥pɯ̥kɯ), biʃibiʃi (*biʃipi̥ʃi), dzɯdazɯda (*dzɯdatsɯ̥ta), dzɯgazɯga (*dzɯgatsɯ̥ka), dzɯgizɯgi (*dzɯgitsɯ̥ki, dzɯki̥tsɯ̥ki)

c. Word-particle boundary (voicing rather than devoicing): hiʒi-gara (*hitʃ̥i-kara) /pizi-kara/ ‘from an elbow’, mizɯ-ga (*mitsɯ̥-ka) /mizu-ka/ ‘water?’ (/-ka/ is an interrogative particle)

d. Word boundary: hibi kireda (*hipi̥ kireda) /pibi kire-ta/ ‘got chapped’, kɯ: dʒigaN ne: (*ku: tʃ̥ikaN ne:) /kuw-u zikaN ne:/ ‘There is no time to eat’

The targets of consonant devoicing are /z/ and /b/. The voiced velar stop /g/ is exempt from consonant devoicing even when it stands before high vowel + voiceless obstruent sequences. The /g/ is realized as [ŋ] in the environment where consonant devoicing applies. The form undergoing sequential voicing [neŋɯse] (/ne-kuse/) is never realized as *[nekɯse]. This form is suggestive in considering the grammatical nature of consonant devoicing. The blockage of devoicing to /g/ is considered to be due to the nasality of [ŋ]. In this dialect, sonorant, including nasal never undergoes devoicing (This restriction is not true for some dialects spoken in Tohoku area. Readers, who have interest in this variation, may refer to Saito 2000). The phoneme /g/ behaves like nasal in not allowing consonant devoicing. However, the phoneme /g/ behaves like other voiced obstruents for sequential voicing despite its surface appearance of [ŋ]. The /g/ in the second element of a compound blocks sequential voicing, like other voiced obstruents. This mixed behavior of /g/ indicates that the two processes, i.e., consonant devoicing and sequential voicing apply at different levels. Consonantal devoicing is regarded as a process occurring at the "surface" level because it is sensitive to the phonetic realization of /g/, while sequential voicing is regarded as a process occurring at the "deep" level because it is sensitive to the /g/’s underlying feature composition. I will return to this point in 2.2.5, where I treat the interaction of phonological processes relevant for the hardening alternation.

Sasaki (2004b) argues that the consonant devoicing can be regarded as a result of the interaction of phonotactic constraints concerning laryngeal specification of neighboring consonant and vowel and the difference between consonant devoicing and high vowel devoicing is accounted for by the permutation of the phonotactic constraints. Though the decomposition of consonant devoicing into more basic phonotactic constraints has a merit by enabling us to put the consonant devoicing in this dialect not only in the cross-dialectal context but also in the cross-linguistic context, I assume a single phonotactic constraint behind the consonant devoicing for presentational purposes

in this paper.

2.2.5. Overlap of the environment: Interaction

The domain of the four phonological processes differs: the domain for sequential voicing is compounding, the smallest among them, consonant devoicing occurs only inside the word, and continuancy neutralization and p-->h occur everywhere, although the manner of application of continuancy neutralization and p-->h is not the same, i.e., there is no exception for continuancy neutralization but p-->h has exceptions, [p] in onomatopoeia and loanwords and derived [p]s exempt from p-->h. When the second element of a compound begins with a /voiceless non-velar obstruent + high vowel + voiceless obstruent .../ sequence, the conditions for the four phonological processes may overlap and these processes interact. The hardening occurs as a result from the interaction of these processes. The data in (15) below illustrates the interactions.

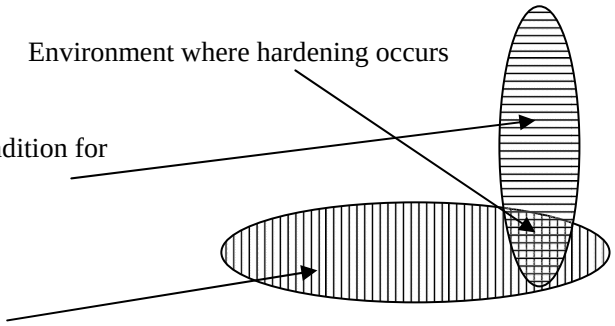
(15)	Sequential voicing	Consonant devoicing
a. /ago-pige/ [aŋoçiŋe] ‘beard’	n.a.	n.a. (no trigger) cf. [çiŋe] /pige/ ‘beard’
b. /ko-sima/ [koʒima] ‘small island’	applied	n.a. (no trigger) cf. [ʃima] /sima/ ‘island’
c. /sakura-pubuki/ [sagɯrafɯ̥pɯ̥ki] ‘cherry blossom storm’	n.a.	n.a. cf. [ɸɯ̥pɯ̥ki] /pubuki/ ‘snowstorm’
d. /ne-pusoku/ [nepɯ̥sogu] ‘lack of sleep’	applied	applied cf. [ɸɯ̥sogu] /pusoku/ ‘lack’
e. /bane-sikake/ [baneʧ̥ikage] ‘spring-powered device’	applied	applied cf. [ʃ̥ikage] /sikake/ ‘device’
f. /ko-tuke:/ [kotsɯ̥ke:] ‘pocket money’	applied	applied cf. [tsɯ̥ka:] /tukaw-u/ ‘use-pres’
g. /baka-tikara/ [bagatʃ̥ikara] ‘prodigious strength’	applied	applied cf. [tʃikara] /tikara/ ‘power’

When the conditions for both sequential voicing and consonant devoicing are not met, the hardening does not occur as shown in (15a). In (15a), not only the underived form but also the second element of the compound undergo p-->h, and the underlying /pige/ realizes as [çiŋe] in both environment. In (15b), the condition for sequential voicing is met but the condition for consonant devoicing is not because the second element of the compound does not include a voiceless obstruent in the onset of the second syllable. In this situation, sequential voicing applies but hardening does not occur. In (15c), the underlying form of the second element of the compound does not meet the condition for sequential voicing because it includes a voiced obstruent /b/. The phonetic form of the compound in (15c) has a potential trigger for consonant devoicing, i.e., voiceless obstruent, in the onset of the second syllable of the second element in compound, but there is no target for consonant devoicing,

i.e., the voiced obstruent in the onset of the first syllable of the second element. The compound in (15c) undergoes neither sequential voicing nor consonant devoicing. This indicates that the application of consonant devoicing depends on the application of sequential voicing. Instead the /p/ in the initial position of the second element undergoes p-->h as in the case of the underived form and the alternation is not found.

The examples in (15d) and (15e) illustrate the hardening alternations in the forms of h--p and s--ts, respectively. In both cases, the conditions for sequential voicing and consonant devoicing are met in the same locus. The situation is schematized as in Fig 1.

Fig 1. Overlap



In (15d), the underived form of /pusoku/ is realized as [ɸɯ̥sogɯ], undergoing p-->h and the /pusoku/ as a second element of the compound is realized as [...-pɯ̥sogɯ]. The /pusoku/ -- [...-pɯ̥sogɯ] mapping in the compound is obtained from the opaque interaction between sequential voicing and consonant devoicing. Consonant devoicing (b-->p) counterfeeds sequential voicing (p-->b). The debuccalization process p-->h has no effect on the [p] derived through consonant devoicing because p-->h is bled by sequential voicing. The hardening counterpart can be regarded as a result from a type of Duke-of-Yoku Gambit interaction (Pullum 1976) between sequential voicing and consonant devoicing (For voicing specification, the consonant undergoing voiceless → voiced → voiceless derivation in terms of serialist formalism). The hardening "alternation" or "pair" is obtained by the emergence of [h] in the underived form through the application of p-->h.

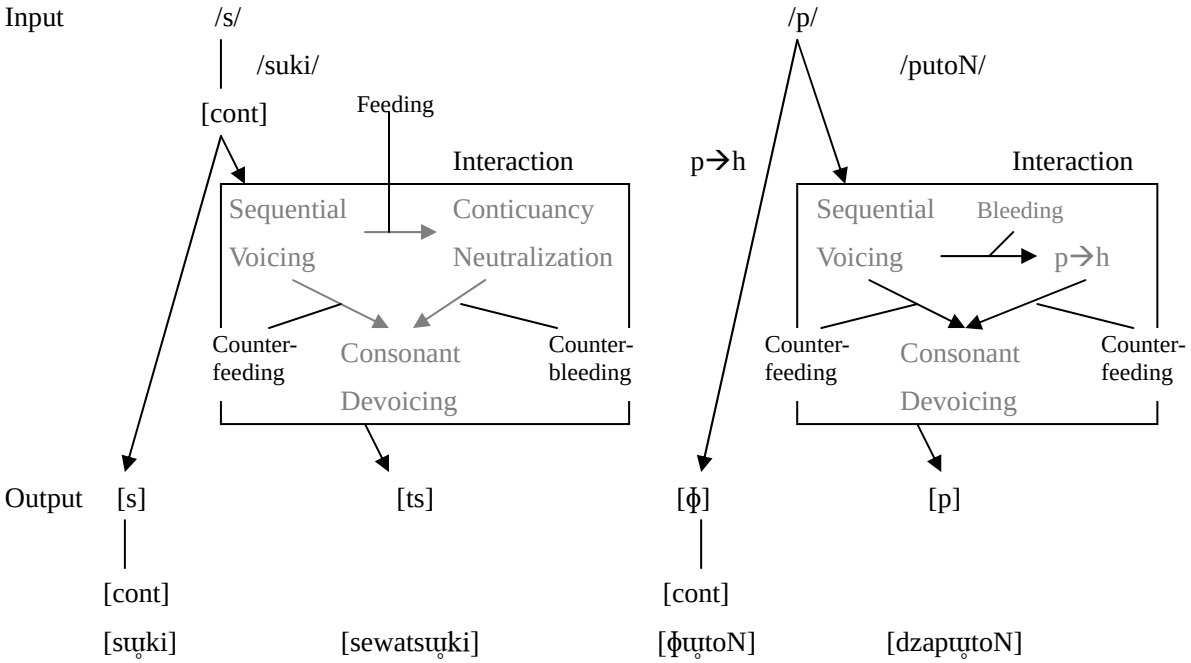
The s--ts alternation in (15e) can be captured through the serialist approach as follows. The underlying representation of the second element of the compound /sikake/ satisfies the condition for sequential voicing and the sequential voicing converts the initial /s/ to z. The *z* derived through sequential voicing stands before the high vowel *i*. Continuancy neutralization is required in this environment. Consonant devoicing applies to the voiced coronal obstruent losing its [continuant] specification as a result of continuancy neutralization. The result is [ts], the allophone of /t/ classified as an unmarked member of voiceless coronal obstruents for continuancy.

The overlap of conditions for sequential voicing and consonant devoicing not always results in hardening. As illustrated in (15f-g), when the initial consonant of the second element of

compound is /t/, no alternation occurs. This can be regarded as a Duke-of-York Gambit interaction between sequential voicing and consonant devoicing, i.e, the underlying /t/ turns into *d* through sequential voicing and this *d*, standing before a high vowel, vacuously satisfies continuancy neutralization because of its lack of [continuant] specification (I assume the feature continuant as a privative feature), succeeding application of consonant devoicing converts *d* to *t* and this *t* is realized as [ts] through the application of allophonic rule (affrication of *t* before high vowels).

The overlapping of the conditions for sequential voicing and consonant devoicing plus active engagement of p-->h and continuancy neutralization yields the hardening alternation. The interaction among the four phonological processes can be schematized as in Fig 2.

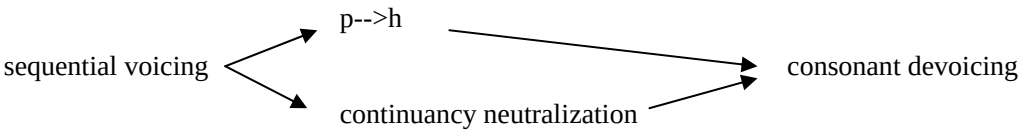
Fig 2. Interactions of phonological processes behind hardening alternation



There are two ways of explaining the interaction of phonological processes, i.e., serialism and parallelism. The serialism is predominant in the traditional generative phonology, while the parallelism is basic for Optimality Theory, at least in its classic form (Prince & Smolensky 1993).

The interaction schematized in Fig 2 is captured in serialist theory as in (16). Sequential voicing applies before continuancy neutralization because of their feeding relationship. Sequential voicing applies before p-->h because of their bleeding relationship. Continuancy neutralization and p-->h apply before consonant devoicing. The precedence relationship between continuancy neutralization and consonant devoicing is sanctioned by the fact that continuancy neutralization feeds consonant devoicing. The precedence relationship between p-->h and consonant devoicing is ensured by the fact that consonant devoicing counterfeeds p-->h.

(16) Serial ordering of the relevant processes



When we add another process concerning voicing alternation, i.e., intervocalic voicing, to the consideration, a different picture emerges about the relationship between continuancy neutralization and consonant devoicing. Mediated by intervocalic voicing, continuancy neutralization applies after consonant devoicing. As mentioned in 2.2.2, intervocalic voicing feeds continuancy neutralization. The condition for consonant devoicing is more specific than that for intervocalic voicing because the former requires the vowel between target and trigger be high, while the later has no restriction on vowel height surrounding the target stop. From this specificity of condition, consonant devoicing is assumed to apply before intervocalic voicing. Under the framework of Lexical Phonology (Kiparsky 1982, 1985), this rule sandwitching can be regarded as a reflection of the fact that continuancy neutralization is active in both lexical and postlexical modules.

(17) Lexicon (word-internal domain)
sequential voicing
p-->h
continuancy neutralization
Postlexical module
/g/-->ŋ/V__V
consonant devoicing
intervocalic voicing
continuancy neutralization

The division of module and the classification of processes above accommodate the interaction relevant for the hardening alternations. The lexical and postlexical status of each process is supported by the grammatical behavior. Sequential voicing is a process specific for compound formation. This property demonstrates its lexical status. The lexical status of p-->h is guaranteed by the fact that it has lexical exceptions, i.e., the lexical item of loan word and onomatopoeia exempt from this process. The postlexical status of consonant devoicing is visible from the non-structure preserving manner of its application, i.e., consonant devoicing accompanies devoicing of high vowel between trigger (voiceless obstruent) and target (voiced obstruent) and yields [i̥] and [ɯ̥], the allophones of /i/ and /u/ respectively. The postlexical status of consonant devoicing is also visible from the interaction with another allophonic rule. The fact that /g/ (surface [ŋ]) is exempt from consonant devoicing indicates that consonant devoicing applies after the allophonic rule

/g/-->ŋ/V__V. The ordering sequential voicing --> devoicing is also ascertained by the fact that the [ts] and [p] derived through devoicing in the second element block sequential voicing. As mentioned in 2.2.4, /g/ exempt from consonant devoicing due to the nasality of the allophone [ŋ]. Intervocalic voicing applies not only inside the word but also at the word-particle boundary. This domain of application indicates that intervocalic voicing is a process applying out of the lexicon.

In the following sections, I examine whether OT, a parallelist theory, can capture the interaction described above or not. It will be argued that a weak parallelist modification is necessary.

3. Failed evaluation with Classic OT

Optimality Theory is a formal theory advocated by Prince & Smolensky (1993), accounting for grammatical phenomena through the evaluation of candidates generated by Gen from the input with ranked and violable constraints. The output is regarded as the most harmonic candidate. In its classic form, OT is a parallelist theory, where the input is directly mapped onto the output with no intermediate levels.

In OT, phonological process or rule is a derived notion and the grammars of languages differ not by the existence or absence of processes or rules but in the manner of constraint interaction. The application and non-application of phonological processes is assumed to be derived by the relative ranking of the markedness constraints (M(P)) or alignment constraints banning a certain phonological structure and the faithfulness constraints (F(P)) prohibiting the modification of the phonological structure banned by M(P). When M(P) is ranked above F(P), a phonological process occurs in a manner avoiding the structure banned by M(P). On the other hand, if M(P) is dominated by F(P), no alternation happens.

The constraints and partial rankings for the four phonological processes relevant for the hardening alternation are provided in (18). Following Ito & Mester (2003), I assume that a type of morpheme realization constraint (advocated by Kurisu 2001), which requires the feature-sized morpheme composed of [voice] to be linked to the initial obstruent of the second element of a compound, is responsible for sequential voicing. This constraint is dominated by the OCP constraint concerning [voice] and it incurs sequential voicing only when sequential voicing does not result in the violation of OCP.

(18) Partial rankings for individual processes

a. Sequenatial voicing: OCP >> SeqVoi >> Id(voice)

OCP: Avoid multiple occurrence of [voice] within a stem.

SeqVoi: Link the feature-sized morpheme [voice] to the initial obstruent of second element of compound.

Id(voice): Do not alter the specification of [voice].

b. p-->h: *p >> Id(cont), Id(place)

*p: Avoid single occurrence of [p].

Id(cont): Do not alter the specification of [continuant].

c. Continuancy neutralization: * ConNeut >> Id(cont)

ConNeut: Specification of [continuant] for the voiced coronal obstruent before high vowel or glide is prohibited.

d. Consonant devoicing: Dev >> Id(voice)

Dev: The structure /...C̬V$_{[high]}$C̬V.../ is prohibited.

(19) Combined ranking

OCP, Dev >> *p, ConNeut >> SeqVoi >> Id(voice), Id(cont)

The constraint ranking presented in (19) evaluates the underived forms and the forms undergoing each process correctly. See the tableaux in (20). The small *v* attached above left of second element of compound stands for the feature-sized morpheme for sequential voicing.

(20) Evaluation for each process

a. Sequential voicing: s-->z

	/ao-^{v}sora/	OCP	Dev	*p	ConNeut	SeqVoi	Id(voi)	Id(cont)
☞	aozora						*	
	aosora					*!		

b. Sequential voicing: p-->b

	/eke-^{v}pana/	OCP	Dev	*p	ConNeut	SeqVoi	Id(voi)	Id(cont)
☞	egebana						*	
	egehana					*!		
	egepana			*!		*		

c. p-->h, hana > pana

	/pana/	OCP	Dev	*p	ConNeut	SeqVoi	Id(voi)	Id(cont)
☞	hana							*
	pana			*!				

d. Continuancy neutralization (with sequential voicing)

	/baka-^{v}tura/	OCP	Dev	*p	ConNeut	SeqVoi	Id(voi)	Id(cont)
☞	bagaZɯra						*	*
	bagadzɯra				*!		*	
	bagatsɯra					*!		

However, with the constraint ranking (19), the forms undergoing hardening, i.e., both sequential voicing and consonant devoicing, are evaluated as suboptimal. The constraint ranking (19) makes the wrong prediction for hardening. The failed evaluations are illustrated in (21). Under the ranking (19), for coronal consonant, the faithful candidate is evaluated as most harmonic. The tableau (21a) shows that the faithful candidate, the candidate undergoing sequential voicing and the candidate

undergoing both sequential voicing and devoicing violates the higher ranked markedness constraints. They differ in the violation of the faithfulness constraint. The candidates other than the faithful candidate violate some faithfulness constraint(s). On the other hand, the faithful candidate does not incur a faithfulness constraint violation. The actual form [sewatski], undergoing hardening, is evaluated less harmonic than the faithful candidate due to its violation of the faithfulness constraint.

(21) Failed evaluation

a. /sewa-^{v}suki/ → *sewasu̥ki

a.	/sewa-^{v}suki/	OCP	Dev	*p	ConNeut	SeqVoi	Id(voi)	Id(cont)
☞	sewasu̥ki					*		
	sewazɯki		*!				*	
Actual	sewatsu̥ki					*		*!

b. /za-^{v}putoN/ → dzaɸu̥ton

	/za-^{v}putoN/	OCP	Dev	*p	ConNeut	SeqVoi	Id(voi)	Id(cont)
Actual	dzapu̥toN			*!		*		
	dzabɯtoN		*!				*	
☞	dzaɸu̥toN							*

In order to accommodate the data, certain modifications are required. I will propose a weak parallelist solution with level ordering within the framework of Stratal OT (Kiparsky 2000).

4. Stratal-OT solution

In 2.2.5, I argued that the division of phonology into lexical and postlexical modules is required for capturing the interaction of phonological processes around hardening within a serialist model. Therein, each phonological process belongs to lexicon or post lexicon except for continuancy neutralization belonging to both lexicon and postlexicon due to the rule sandwitching.

The processes within each module interact transparently. In the lexicon, sequential voicing bleeds p-->h and feeds continuancy representation. In the postlexical module, consonant devoicing bleeds intervocalic voicing and intervocalic voicing feeds continuancy neutralization. Transparent (feeding and bleeding) interactions are captured not only through rule ordering but also through parallelist evaluation with constraint ranking.

However, opaque interactions are not captured correctly within a parallelist account without some modifications as illustrated in Section 3. The opaque interactions are found in the interaction between a lexical process and a postlexical process. Consonant devoicing conterfeeds sequential voicing and p-->h and counterbleeds continuancy neutralization.

The situation, where the opaque interactions are found only between phonological processes belonging to the different modules, seems to be compatible with a weak parallelist extension of OT, i.e., Stratal OT advocated by Kiparsky (2000).

Stratal OT is a weak parallelist version of OT, which recognizes co-phonologies for the grammar of a given language. In this theory, each stratum (or level) can have a distinct constraint ranking and the output of a smaller domain corresponds to the input of a larger domain. For instance, the output of stem-level corresponds to the input for word-level.

In order to capture the opaque interactions behind the hardening alternation, I assume two levels, i.e., lexical and postlexical levels. The constraint ranking for each level is provided in (22).

(22) a. Lexical: OCP, *p, ConNeut >> SeqVoi >> Id(voi), Id(cont) >> Dev
b. Postlexical: ConNeut, Dev >> Id(voi), Id(cont) >> OCP, *p >> SeqVoi

In the lexical constraint ranking (22a), markedness constraints incurring p-->h, continuancy neutralization and sequential voicing are ranked higher than faithfulness constraints banning these processes, while the constraint Dev responsible for consonant devoicing is lower ranked. Under this constraint ranking, the candidate undergoing p-->h, continuancy neutralization and sequential voicing is evaluated as most harmonic when the input includes the structure penalized by the constraints responsible for these processes. The most harmonic candidate, i.e., the output of this level, corresponds to the input for the postlexical level, where the constraint ranking distinct from that in the lexical level determines evaluation. In the postlexical constraint ranking (22b), markedness constraints responsible for continuancy neutralization and consonant devoicing are ranked higher than faithfulness constraints penalizing these processes, while the constraints, OCP, *p and SeqVoi are ranked lower than faithfulness constraints. Under this constraint ranking, the candidate undergoing consonant devoicing is evaluated as most harmonic when the input, i.e., the output from the lexical level, includes the structure penalized by Dev. The difference between the two constraint rankings is characterized by the partial permutation of constraints, demotion of *p and the constraints responsible for sequential voicing below the faithfulness constraints and promotion of Dev above faithfulness constraints, the positions of ConNeut (responsible for continuancy neutralization) and faithfulness constraints remain intact. (I omit the constraint responsible for intervocalic voicing in order to restrict the discussion to the interaction yielding hardening alternation.)

Evaluation for hardening pairs goes as follows. For the initial /s/ of noun stem in the underived environment, faithful mapping is regarded as most harmonic in both lexical and postlexical levels. See tableaux (23a) and (23b). Thus, the fricative counterpart [s] is obtained in the underived environment. For the stem-initial /s/ before high vowels in the environment satisfying the condition for sequential voicing, lexical constraint ranking evaluates the candidate undergoing both sequential voicing and continuancy neutralization as optimal (‘Z’ stands for the voiced coronal obstruent of which continuancy is unspecified), see (23c). The output, undergoing both sequential voicing and continuancy neutralization in the lexicon, becomes an input for the postlexical module.

The postlexical constraint ranking evaluates the candidate undergoing consonant devoicing as optimal. The candidate [sewatsɯ̥ki] is more harmonic than [sewasɯ̥ki] (faithful for the lexical input) because it does not incur the violation of Id(cont) in postlexical evaluation. See tableau (23d). If the input is z not Z at this level, the situation is reverse. Thus, the 'hard' counterpart [ts] is obtained through the lexical and postlexical evaluation.

(23) Hardening: s--ts alternation

a. Tableau for lexical evaluation of /suki/

/suki/	OCP	*p	ConNeut	SeqVoi	Id(voi)	Id(cont)	Dev
☞ suki							
tsuki						*!	

b. Tableau for postlexical evaluation of /suki/

suki	ConNeut	Dev	Id(voi)	Id(cont)	OCP	*p	SeqVoi
☞ sɯ̥ki							
tsɯ̥ki				*!			

c. Tableau for lexical evaluation of /sewa-^{v}suki/

/sewa-^{v}suki/	OCP	*p	ConNeut	SeqVoi	Id(voi)	Id(cont)	Dev
sewasɯ̥ki				*!			
sewatsɯ̥ki				*!		*	
sewazuki			*!		*		*
☞ sewaZuki						*	*

d. Tableau for postlexical evaluation of /sewa-^{v}suki/

sewaZuki	ConNeut	Dev	Id(voi)	Id(cont)	OCP	*p	SeqVoi
sewasɯ̥ki			*	*!			
☞ sewatsɯ̥ki			*				
sewazɯki	*!	*		*			
sewaZɯki		*!					

The h--p hardening pair is obtained as follows. For /p/ in the underived environment, the candidate undergoing debuccalization (p-->h) is evaluated as optimal and the input /puton/ corresponds to the output futon in this level. See tableau (24a). The output *ɸuton* from the lexicon becomes the input for the postlexical module. As illustrated in tableau (24b) faithful mapping is favorable for the input futon for the postlexical constraint ranking because it does not incur any violation of constraints. Thus, the fricative counterpart [f] is obtained. For the stem-initial /p/ before high vowels in the environment satisfying the condition for sequential voicing, lexical constraint ranking evaluates the candidate undergoing sequential voicing as optimal as illustrated in tableau (24c). The candidate *zabutoN* is selected as an output from the lexicon and becomes an input for the postlexical module. The tableau (24d) shows that the postlexical constraint ranking evaluates the candidate undergoing devoicing, however not p-->h, as optimal. The candidate undergoing both devoicing and p-->h, namely, [dzaɸɯ̥toN], is less harmonic than the opaque candidate [dzapɯ̥toN] because it incurs the

violation of Id(cont) dominating *p in the postlexical constraint ranking. Thus, the 'hard' counterpart [p] is obtained through the lexical and postlexical evaluation.

(24) Hardening: h--p alternation

a. Tableau for lexical evaluation of /puton/

/putoN/	OCP	*p	ConNeut	SeqVoi	Id(voi)	Id(cont)	Dev
putoN		*!					
☞ ɸuton						*	

b. Tableau for postlexical evaluation of /puton/

ɸutoN	ConNeut	Dev	Id(voi)	Id(cont)	OCP	*p	SeqVoi
☞ ɸɯ̥toN							
pɯ̥toN				*!			

c. Tableau for lexical evaluation of /za-^{v}puton/

/za-^{v}ptoN/	OCP	*p	ConNeut	SeqVoi	Id(voi)	Id(cont)	Dev
zaputoN		*!		*			
zaɸutoN				*!		*	
☞ zabutoN					*		*

d. Tableau for postlexical evaluation of /za-^{v}puton/

zabutoN	ConNeut	Dev	Id(voi)	Id(cont)	OCP	*p	SeqVoi
☞ dzapɯ̥toN			*			*	
dzaɸɯ̥toN			*	*!			
dzabɯtoN		*!					

Stratal-OT can account not only for the hardening alternation but also for another phenomenon the strong parallelist approach cannot deal with easily, the covert OCP effect, i.e., sequential voicing blockage by surface [ts] and [p] in the second element of the compound. As illustrated in (5b), the underlying [voice] specification of [p] and [ts] blocks application of sequential voicing in the examples [sagɯraɸɯ̥pɯ̥ki] (/sakura-pubuki/ 'cherry blossom storm') and [bagaʃo:tʃ̥iki] (/baka-sjo:ziki/ 'honest to a fault') despite their surface voicelessness.

The situation can be captured as follows. In the lexicon, where consonant devoicing is off due to the lower ranking of the responsible constraint Dev, the candidate undergoing debuccalization (*sakuraɸubuki*) is evaluated as most harmonic and is selected as output as illustrated in tableau (25a). The candidate undergoing sequential voicing is ruled out for the violation of the undominated constraint OCP. The faithful candidate is banned for the violation of the undominated constraint *p. In the postlexical module, for the input *sakuraɸubuki*, the candidate undergoing consonant devoicing is evaluated as most harmonic (see tableau (25b)). The situation is the same in case of the covert OCP effect with [ts]. As illustrated in tableau (25c), in the lexicon, OCP is operative due to its undominated status. Thus, the faithful candidate is evaluated as optimal despite the violation of SeqVoi. The most harmonic candidate corresponds to the input for the postlexical module. Tableau (25d) illustrates the postlexical evaluation, where the candidate undergoing devoicing is evaluated as

optimal. In both cases, the covert OCP is derived from the undominated status of OCP in the lexicon and the deletion of the blocker of sequential voicing by the consonant devoicing.

(25) Covert OCP effect

a. Tableau for lexical evaluation of /sakura-^{v}pubuki/

/sakura-^{v}pubuki/	OCP	*p	ConNeut	SeqVoi	Id(voi)	Id(cont)	Dev
sakurapubuki		*!		*			
☞ sakuraɸubuki				*		*	*
sakuraɸupu̥ki		*!		*	*		
sakuraɸu̥ɸu̥ki				*	*	*!	
sakurabubuki	*!				*		*

b. Tableau for postlexical evaluation of /sakura-^{v}pubuki/

sakuraɸubuki	ConNeut	Dev	Id(voi)	Id(cont)	OCP	*p	SeqVoi
sagɯraɸɯbɯki		*!					
☞ sagɯraɸu̥pu̥ki			*			*	
sagɯraɸu̥ɸu̥ki			*	*!			

c. Tableau for lexical evaluation of /baka-^{v}sjo:ziki/

/baka-^{v}sjo:ziki/	OCP	*p	ConNeut	SeqVoi	Id(voi)	Id(cont)	Dev
bakasjo:ziki			*!	*			*
☞ bakasjo:Ziki				*		*	*
bakasjo:tʃi̥ki				*	*	*!	
bakazjo:Ziki	*!				*	*	*

d. Tableau for postlexical evaluation of /baka-^{v}sjo:ziki/

bakasjo:Ziki	ConNeut	Dev	Id(voi)	Id(cont)	OCP	*p	SeqVoi
bagaʃo:Ziki		*!					
☞ bagaʃo:tʃi̥ki			*				
bagaʃo:ʃi̥ki			*	*!			

The division of phonology into lexical and postlexical co-phonologies is useful for understanding the grammatical nature of the Mitsukaido dialect at least in two respects, the socio-linguistic context where this dialect is spoken and the parallelism with other components of grammar.

The lexical and postlexical division reflects the geographic situation where the dialect is spoken. The phonological processes active in the lexicon are sequential voicing and p-->h. These are also found in southern Kanto dialects. Sequential voicing in the Mitsukaido dialect yields voiced obstruent. This effect is found in the majority of dialects other than Tohoku dialects, while, in the Tohoku dialects, the process parallel to the sequential voicing is not voicing of the initial element of the second element of compound but prenasalization. Thus, the phonological lexicon in this dialect is similar to that of southern Kanto dialects. Consonant devoicing, the phonological process active in the postlexical module, is also active in Tohoku dialects. However, the result of consonant devoicing is not the same in the Mitsukaido dialect and in the Tohoku dialects. In the Mitsukaido dialect, the

result of consonant devoicing is voiceless obstruents [ts] and [p], while, in the Tohoku dialects, it is the voiceless prenasal stops [˜ts] and [˜p] (see Inoue 1968). This difference is due to the difference of phonemic inventory not to the process itself. Consonant devoicing in both dialects shares the property of deleting voicing specification of obstruents. Thus, the postlexical phonology of the Mitsukaido dialect can be regarded as Tohoku-like. This mixed nature reflects the geographical situation of this dialect. The Mitsukaido dialect is one of the dialects spoken on the boundary area between Tohoku and southern Kanto dialects.

The mixed characteristics are also found in other components of grammar, i.e., morphology and syntax. The Mitsukaido dialect lacks productive anticausative (or spontaneous) morphology, which is characteristic in Tohoku dialects. In this respect, the Mitsukaido dialect is like sounthern-Kanto diaclects. On the other hand, this dialect shares case particles with Tohoku dialects, such as *-sa* (dative/allative) and *-godo* (animate accusative). From these facts, in the non-phonological component of the Mitsukaido dialect, the commonality with southern Kanto dialects is found in the lexicon and that with Tohoku dialects is found in the domain larger than lexicon.

Parallelism between phonology and morphosyntax is easily captured by Stratal OT. Thus, Stratal OT is useful not only for analyzing the opaque interaction around hardening alternations but also for understanding the grammatical system of the Mitsukaido dialect.

In the next section, I examine the other OT extensions relying on the representations other than input and output.

5. Other approaches

In this section, I examine other OT extensions sharing with Stratal OT the property of relying on representations other than input and output, Sympathy theory and Candidate Chain theory (OT-CC), advocated by McCarthy (1999) and McCarthy (2007), respectively. These two extensions are different from Stratal OT in that a single constraint ranking is assumed. Both Sympathy and OT-CC can be regarded as strong parallelist extensions. They are proposed in order to dealing with opaque interactions within OT. Among the strong parallelist extensions, I will examine Sympathy first, and go to OT-CC next.

Sympathy theory is an extension of faithfulness constraints. For classic OT, faithfulness is a relation between input and candidates generated from the input. Sympathy theory also recognizes a faithfulness relation among candidates. The evaluation under Sympathy theory has two steps. First, a certain IO-faithfulness constraint is designated as a selector and the most harmonic member of the candidates satisfying the selector is selected as the sympathetic candidate. Next, candidates are evaluated by the constraint ranking with ㊋O-faithfulness constraint. The ㊋O-faithfulness constraint requires resemblance between the sympathetic candidate and the other candidates.

Sympathy theory can accommodate the h-->p hardening by assuming the Max(subseg), a

faithfulness constraint banning deletion of floating feature or floating node advocated by Zoll (1996), as a selector (I indicate the selector with the heading ✯) and positing an undominated sympathetic constraint Id㊵O(cont) in the ranking (19). In tableau (26), the candidate undergoing sequential voicing (㊵dzabɯtoN) obeys the selector constraint ✯Max(subseg) and is regarded as a sympathetic candidate. This candidate does not survive because of its violation of the undominated constraint Dev. The candidate undergoing p-->h (dzaɸɯ̥toN) is different from the sympathetic candidate in the specification of [continuant] and is evaluated as sub-optimal due to the violation of Id㊵O(cont). The opaque candidate *dzapɯ̥toN* is evaluated as optimal.

(26) Evaluation of h—p hardening by Sympathy theory

	/za-^{v}putoN/	Dev	Id㊵O(cont)	*p	SeqVoi	✯Max(subseg)	Id(voi)	Id(cont)
☞	dzapɯ̥toN			*	*	*		
	dzaɸɯ̥toN		*!		*	*		*
㊵	dzabɯtoN	*!					*	

The s-->ts hardening is captured in the same way as illustrated in tableau (27).

(27) Evaluation of s—ts hardening by Sympathy theory

	/sewa-^{v}suki/	Dev	Id㊵O(cont)	ConNeut	SeqVoi	✯Max(subseg)	Id(voi)	Id(cont)
	sewasɯ̥ki		*!		*	*		
☞	sewatsɯ̥ki				*	*		*
	sewazɯki	*!		*			*	
㊵	sewaZɯki	*!					*	*

However, the same constraint ranking makes the wrong prediction for the covert OCP effects. As illustrated in (5b), [p] in *ɸɯpɯ̥ki* and [ts] in *ʃo:tʃ̥iki* block sequential voicing due to their underlying specification of [voice] when they are the second element of compound. Therefore, the phonetic realization of /sakura-pubuki/ and /baka-sjo:ziki/ are [sagɯraɸɯpɯ̥ki] and [bagaʃo:tʃ̥iki], respectively. However, the candidates undergoing sequential voicing are evaluated as most harmonic in the constraint ranking with Id㊵O(cont) and ✯Max(subseg).

Tableau (28) illustrates the wrong evaluation for the covert OCP effect of [p]. The candidate (28f) is the most harmonic among the candidates satisfying ✯Max(subseg) and it is regarded as a sympathetic candidate. The candidate (28g) is evaluated as optimal because it does not incur violation of undominated constraints. The actual form *sagɯraɸɯpɯ̥ki*, candidate (28b), is ruled out for double violation of Id㊵O(cont).

(28) Wrong evaluation for covert OCP effect of [p] by Sympathy theory

	/sakura-^{v}pubuki/	Dev	Id㊎O(cont)	*p	SeqVoi	✯Max(subseg)	Id(voi)	Id(cont)
	a. sagɯrapɯbɯgi		*!	*	*	*		
!	b. sagɯraɸɯpu̟ki		*!*	*	*	*		
	c. sagɯraɸu̟ɸu̟ki		*!		*	*		
	d. sagɯraɸɯbɯgi		*!*		*	*		
	e. sagɯrabɯpu̟ki	*!	*	*			**	
㊎	f. sagɯrabɯɸu̟ki	*!					**	*
☞	g. sagɯrapu̟ɸu̟ki			*	*	*		

The situation for the covert OCP effect of [ts] is also wrong. The candidate (29h), undergoing both sequential voicing and continuancy neutralization on the initial consonant of the second element and consonant devoicing on the second consonant, is optimal as well as sympathetic. The actual form *bagaʃo:tʃ̟iki*, candidate (29c), is regarded as less harmonic than (29h).

(29) Wrong evaluation for covert OCP effect of [ts] by Sympathy theory

	/baka-^{v}sjo:ziki/	Dev	Id㊎O(cont)	ConNeut	SeqVoi	✯Max(subseg)	Id(voi)	Id(cont)
	bagaʃo:ʒiki	*!		*	*	*		
	bagaʃo:Ziki	*!			*	*		*
!	bagaʃo:tʃ̟iki		*!*		*	*	*	*
	bagaʃo:ʃ̟iki		*!			*	*	
	bagaʒo:ʒiki	*!	*	**			*	
	bagaZjo:Ziki	*!	*				*	**
	bagaʒo:tʃ̟iki		*!*	*			**	*
	bagaZjo:tʃ̟iki		*!				**	**
☞㊎	bagaZjo:ʃ̟iki						**	*

The wrong evaluation in (28) and (29) is due to the undominated status of Dev. Satisfaction of this constraint results in consonant devoicing in the second onset of the second element of the compound. Consonant devoicing removes the blocking element of sequential voicing, i.e., [voice] specification in non-initial onset. In this situation, the candidate undergoing both sequential voicing and consonant devoicing is preferable because it does not incur the violation of OCP. Thus, one of the candidates undergoing sequential voicing is selected as the sympathetic candidate in (28) and (29), and plays a crucial role in the wrong evaluation. The constraint ranking with sympathy constraint prefers the candidate undergoing both sequential voicing and consonant devoicing. This results in the correct evaluation in case of hardening, where the locus of two phonological processes overlaps, but the

wrong evaluation in case of the covert OCP effect, where the locus of two phonological processes does not overlap.

Sympathy theory can account for hardening but not for covert OCP effect, while Stratal OT can handle both hardening and covert OCP effect (see tableaux in (23), (24) and (25)). The covert OCP effect is derived by the same phonological processes yielding hardening alternations. The difference lies in the locus of application. Thus, Sympathy theory cannot capture the whole range of behavior of the phonological processes composing hardening alternations. Stratal OT is superior to Sympathy theory in that it accounts not only for hardening itself but also for the related phenomena.

The situation with OT-CC is much worse than Sympathy theory. OT-CC cannot deal with the hardening alternation.

In OT-CC, the object of evaluation is not an individual candidate but a candidate chain. A candidate chain $<f_0, f_1, ..., f_n>$ is formed subject to several conditions (McCarthy 2007:61). *Faithful first member* requires that the first member of every candidate chain based on the input /in/ is a fully faithful parse of /in/. *Gradualness* requires that a form adds exactly one locally unfaithful mapping to those of its immediate predecessor. *Local optimality* requires that non-initial form in a chain is more harmonic than its predecessor.

Opaque interactions of phonological processes are captured by Prec constraint, a constraint requiring precedence relation among violations of fathfulness constraints in the candidate chain. Prec(A, B) demands that a faithfulness constraint A be violated before another faithfulness constraint B in a given candidate chain. The violation mark is added for Prec(A, B) when violation of B is not preceded by the violation of A or when A is violated after the violation of B. When both faithfulness constraints A and B dominate Prec(A, B), transparent (feeding or bleeding) interactions are obtained. Under the ranking *A, *B >> B >> Prec(A, B) >> A, where the constraints *A and *B stand for the markedness constraints incurring phonological processes resulting in the violation of faithfulness constraints A and B, respectively, opaque interaction, where a phonological process caused by *A counterbleeds a phonological process caused by *B, is obtained. The opaque interaction, where a phonological process caused by *A counterfeeds a phonological process caused by *B, is obtained under the ranking, *B >> B >> Prec(A, B) >> *A >> A.

OT-CC makes the wrong prediction for s--ts hardening. The transparent interaction where sequential voicing feeds continuancy neutralization is captured by the constraint ranking (30). Under this constraint ranking, the candidate chain such as <ko-sima, koʒima, koZima> is evaluated as the most harmonic.

(30) SeqVoi >> ConNeut >> Id(voice), Id(cont) >> Prec(Id(voice), Id(cont))

The counterbleeding interaction between continuancy neutralization and consonant devoicing is

obtained by the constraint ranking (31). This constraint ranking evaluates the candidate chain <ʃo:ʒiki, ʃo:Ziki, ʃo:tʃ̥iki> as the most harmonic.

(31) ConNeut >> Dev >> Id(voi) >> Prec(Id(cont), Id(voi)) >> Id(cont)

However, the constraint ranking combining (30) and (31) makes the wrong evaluation on the interaction among the three phonological processes yielding hardening. Tableau (32) illustrates this wrong evaluation. For presentational purposes, I put only the final members of the candidate chain in the tableaux below.

(32)

/sewa-^{v}suki/	SeqVoi	ConNeut	Dev	Id(voi)	Prec(Id(cont), Id(voi))	Id(cont)	Prec(Id(voi), Id(cont))
☞ a. sewa^{v}sɯki	*!						
b. sewazɯki		*!	*	*	*		
c. sewaZɯki			*	*	*	*	
! d. sewatsu̥ki	*!			**	*	*	

The most harmonic candidate chain is (32c) which undergoes both sequential voicing and continuancy neutralization. In the candidate chain (32c), <sewasɯki, sewazɯki, sewaZɯki>, the second member *sewazɯki* is more harmonic than the first member *sewasɯki* in that it improves violation of the undominated constraint SeqVoi, and the final member *sewaZɯki* is more harmonic than the second member in that it improves violation of ConNeut. The chain formation goes well at this point. However, the candidate chain (32d), <sewasuki, sewazɯki, sewaZɯki, sewatsu̥ki>, of which the final member corresponds to the actual form, is evaluated as less harmonic than the candidate chain (32c) because the final member *sewatsu̥ki* incurs a violation of the undominated constraint SeqVoi while it improves violation of Dev.

OT-CC also makes the wrong prediction for h--p hardening. The bleeding interaction between debuccalization of /p/ and sequential voicing is captured by the partial ranking (33).

(33) *p, SeqVoi >> Id(cont), Id(voi) >> Prec(Id(voi), Id(cont))

The counterfeeding interaction between sequential voicing and consonant devoicing may be captured by the ranking (34). The constraint ranking (24) is contradictory with the constraint ranking in (32) in that Dev dominates SeqVoi in (34) while Dev is dominated by SeqVoi in (32). Even if this

contradiction is ignored, OT-CC cannot make a correct prediction for h—p hardening.

(34) Dev >> Max(subseg) >> Prec(Id(v), Max(subseg)) >> SeqVoi >> Id(v).

The wrong evaluation with the constraint ranking combining (33) and (34) is illustrated in (35). The most harmonic candidate chain is (35a) which includes only the initial member. The final (and also initial) member in (35a) is different from the actual form, the opaque candidate, in that high vowel following [p] is not devoiced. This is a wrong evaluation.

(35) Wrong evaluation with OT-CC for h—p hardening

	/za-ᵛputoN/	Dev	Max(subseg)	Prec(Id(voi), Max(subseg))	*p	SeqVoi	Id(voi)	Id(cont)	Prec(Id(voi), Id(cont))
☞	a. dzaᵛpɯtoN				*	*			
	b. dzabɯtoN	*!					*		
!	c. dzapɯ̥toN		*!		*	*	*		
	d. dzaɸɯ̥toN		*!			*	*	*	

The examination above indicates that Sympathy theory and OT-CC are not available options for dealing with the hardening alternation. It is not clear whether certain modifications improve the situation or not. However, even if a certain modification would enable Sympathy or OT-CC to deal with the situation around hardening alternation, these theories still could not capture the phenomena within the whole picture of the grammar, e.g., parallelism between phonology and morphosyntax and within a socio-linguistic situation as successful as Stratal OT.

6. Conclusion

In this article, I clarify that there is an opaque interaction which cannot be accounted for within OT without introducing serialism through the examination of the hardening alternation in the Mitsukaido dialect of Japanese. I proposed a weak serialist solution for the hardening alternation, postulating distinct constraint rankings for the lexical and postlexical modules. Introducing level ordering is useful not only for accounting for the opaque interaction around the hardening alternation but also for deepening the understanding of the structure of this dialect in that it enables us to capture the phonology -- morphosyntax parallelism and to reflect the socio-linguistic situation of the dialect, i.e., the southern Kanto-like lexicon and Tohoku-like postlexical module.

It is apparent from the discussion in this paper that Stratal OT, a weak parallelist approach,

is superior to strong parallelist extensions such as Sympathy theory or OT-CC for the solution of the phonological opacity around the hardening alternation. However, this does not amount to stating that the Stratal OT approach is the best solution for all opacity cases. Opaque interaction within a single stratum is out of scope for Stratal OT. For such opaque interactions, strong parallelist extensions may be effective. For example, Paradigm Uniformity (Steriade 2000) provides a convincing solution for the counterbleeding opacity between voicing assimilation and velar deletion in Standard Japanese verb morphology (for detail of the analysis, see Sasaki 2005). Seeking out the optimal solution for each problem leads us to the understanding of the nature of phonological opacity.

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