Interactions between Similarity and Proximity in Dissimilation: Swedish Case Study

Hayeun Jang

1. Introduction

It has been explained that dissimilation and co-occurrence restrictions are usually motivated by the Obligatory Contour Principle (henceforth, OCP). The OCP is traditionally formalized as in (1). According to this definition, only the endpoints of proximity (*adjacent*) and similarity (*identical*) scales are considered. This means that the scales are binary: *adjacent* vs. *non-adjacent* for proximity, and *identical* vs. *non-identical* for similarity. In order to prohibit the correct structures, the two scales must be considered together: target elements are prohibited if and only if they are both adjacent and identical.

(1) Obligatory Contour Principle (McCarthy 1986; see also Leben 1973; Goldsmith 1976)
At the melodic level, *adjacent identical* elements are prohibited.

For gradient dissimilation restrictions referring to more fine-grained scales, intermediate points on scales of proximity and similarity can play a role (Pierrehumbert 1993; Frisch et al. 1997, 2004; Suzuki 1998; Harrikari 1999). Gradient dissimilatory patterns show various degrees of interactions between similarity and proximity. The traditional formalization of the OCP cannot explain these interactions except for the extreme case where two adjacent identical elements are targets.

In this paper, I propose a new formalization of the OCP as a family of markedness constraints that incorporate various degrees of interaction between similarity and proximity along continuous scales. I will show that there are gradient patterns of high tone dissimilation in Swedish (Harrikari 1999) that will necessitate a new formalization of the OCP. This case study of Swedish shows that the newly formalized OCP can model complex and gradient dissimilation which cannot be explained by the traditional OCP.

The rest of the paper is structured as follows. Section 2 presents the Swedish data that forms the basis of the argument, focusing particularly on gradient dissimilatory patterns showing interactions between similarity and proximity. Section 3 proposes a new formalization of the OCP as a family of markedness constraints sharing targets and two continuous scales of similarity and proximity, and argues that Swedish patterns can only be captured if the OCP is re-formalized as proposed. Section 4 compares two alternative formalizations of the OCP to the new proposal. Section 5 concludes.

2. Swedish high tone dissimilation

Swedish has two types of word accent, in addition to a focus accent (Bruce 1977, 1990). Precise intonation patterns associated with these accents vary depending upon dialect (Bruce 2007). This paper focuses on data from Central Swedish used in the Stockholm area. Both Accent I and Accent II have a falling contour consisting of a high tone and a following low tone. Accent I has a leading high tone and an accented low tone (L*), while Accent II has an accented high tone (H*) and a trailing low tone. In Swedish, stressed syllables are always heavy with two morae. Accented tones are associated with their corresponding stressed syllable; specifically, they are aligned to the leftmost mora of their stressed syllable as in (2) and (3). Leading high tones of Accent I are realized only when there is a syllable

* Hayeun Jang, University of Southern California, hayeunja@usc.edu. Thanks to Rachel Walker, Karen Jesney, Louis Goldstein, Khalil Iskarous, and members of USC PhonLunch for feedback on this project, and to the audience at SCAMP 2016, CLS 52, and WCCFL 34 for helpful comments.

preceding a stressed syllable as in (3a), compared to (2a). Focus accent is realized as an additional high tone (<u>H</u>) following lexical tones. Focal tones become up-stepped (<u>H↑</u>) after Accent II words as in (2b) and (3b).

(2) Focused words with initial stress (Gussenhoven 2004; Moraic representation is added here.)

```
a. Accent I                          b. Accent II
 ˈan  dɛn   'the duck'                ˈan  dɛn   'the ghost'
 μ μ   μ                              μ μ   μ
 | |                                  | |   |
L* H                                 H* L  H↑
```

(3) Focused words with non-initial stress (Gussenhoven 2002; Moraic representation is added here.)

```
a. Accent I                          b. Accent II
 mɛd  ˈan  dɛn   'with the duck'      mɛd  ˈan  dɛn   'with the ghost'
  μ    μ μ   μ                         μ    μ μ   μ
  |    | |                                  | |   |
  H   L* H                                 H* L  H↑
```

In Swedish, when a focal high tone is followed by an unaccented lexical high tone, high tone dissimilation takes place. The patterns of dissimilation show a three-way gradient distinction depending on proximity (Bruce 1977, 1990; Harrikari 1999). In the case of Swedish, the proximity scale refers to the moraic distance between targets: no intervening mora is defined as *adjacent*, one intervening mora as *close*, and two or more intervening morae as *far*. The similarity scale refers to the tonal register of two target tones: totally identical target tones without any difference of tonal register are defined as *identical*, target tones which are the same kind of tones with some differences of tonal register (high tones which are up-stepped (H↑) or down-stepped (H↓)) as *similar,* and totally different tones (low tone vs. high tone) as *distinct*. If two high tones are *adjacent* with no intervening mora between them in the underlying form, the post-focal high tone is deleted when the two high tones are *identical* as in (4a) or *similar* as in (4b).

(4) Two high tones are underlyingly *adjacent* and

```
a. idential                                  b. similar
 μ  μ          μ  μ                           μ  μ          μ  μ
 |  |    →     |                              |  |    →     |
 H  H          H                              H↑ H          H↑

'longer numbers'                             'long disks'
ˈlɛŋ:re ˈnum:ɛr     *ˈlɛŋ:re ˈnum:ɛr          ˈlɔŋ:ɑ   laˈmɛl:lɛr       *ˈlɔŋ:ɑ   laˈmɛl:lɛr
 / \ |   /\  |        / \ |   /\  |            / \ |   | / \ |            / \ |   | / \ |
μ μμ  μμ  μ          μ  μ  μ  μμ  μ           μ μ μ  μ  μ μ μ          μ  μ  μ  μ μμ μ
|  |     |           |  |  |  |               | | |     |               |  |  |  | |
L* H    L*           L* H  H  L*              H* L H↑   L*              H* L H↑ H L*
```

(5) Two high tones are underlyingly *close* and

```
a. identical                                 b. similar
 μ  μ  μ        μ  μ  μ                       μ  μ  μ
 |     |   →    |     |                       |     |
 H     H        H     H↓                      H↑    H

'longer disks'                               'long enemas'
ˈlɛŋ:re  laˈmɛl:lɛr    *ˈlɛŋ:re  laˈmɛl:lɛr   ˈlɔŋ:ɑ   laveˈmaŋ:
 / \ |    |  /\  |       / \ |    |  /\  |      / \ |   | |   / \
μ  μμ   μ  μμ  μ        μ  μμ   μ  μμ  μ       μ μμ   μ μ μ μ
|  |     | |            |  |     | |           | | |     | |
L* H     H↓ L*          L* H     H  L*         H* L H↑   H L*
```

In an underlying form, if there is an intervening mora between two target high tones (*close* in terms of proximity) as in (5), pairs of identical high tones and pairs of similar high tones show different dissimilatory patterns. When the two high tones are underlyingly *close* and *identical*, the second high tone becomes down-stepped in its surface form as in (5a). When the two target high tones are *close* and *similar* in an underlying form, there is no tonal change in its surface form as in (5b).

If two high tones are *far* enough apart with two or more intervening morae between them in an underlying form, there is no tonal change in the surface form even when they are *identical* as in (6).

(6) Two high tones are underlyingly *far* and *identical*

```
μ  μ  μ  μ
|        |
H        H

'longer enemas'
ˈlɛŋ:re  laveˈmaŋ:
 / \  |   |  |   /\
μ  μ  μ  μ μ   μ μ
|   |        |  |
L* H        H  L*
```

The dissimilatory patterns of Swedish show that proximity and similarity both come into play in high tone dissimilation: the closer two high tones are, the less similar they can be. Two *adjacent* high tones are not allowed regardless of their similarity, two *close* high tones are allowed only when they are not identical (*similar* or *distinct*), and two *far* high tones are allowed even when they are *identical*. In order to properly ban certain pairs of high tones, both similarity and proximity scales must be considered together. The dissimilatory patterns of Swedish are schematized as in Figure 1. In the figure, gray-colored cells represent pairs of high tones which are not allowed in Swedish. The patterns show interactions of two ternary scales of similarity (*identical* vs. *similar* vs. *distinct*) in terms of tonal register and proximity (*adjacent* vs. *close* vs. *far*) in a prosodic word. Markedness relativized to the OCP is increased as shown by the arrows: for similarity, *identical* is more marked than *similar*, and for proximity, *adjacent* is more marked than *close*. The traditional OCP cannot explain the Swedish dissimilation patterns except for (4a) where two adjacent identical high tones are targets. In order to explain all the Swedish patterns, the OCP must be re-formalized to incorporate various degrees of interactions of two scales of similarity and proximity.

Figure 1. Interactions of two ternary scales in Swedish high tone dissimilation
(Gray-colored cells represent the prohibited pairs of high tones in Swedish.)

	far	***close***	***adjacent***
identical	**(6)** *far & identical*	**(5a)** *close & identical*	**(4a)** *adjacent & identical*
similar	*far & similar*	**(5b)** *close & similar*	**(4b)** *adjacent & similar*
distinct	*far & distinct*	*close & distinct*	*adjacent & distinct*

3. The new formalization of the OCP

3.1. Proposal

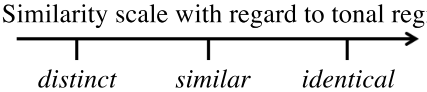
In this paper, I propose a new formalization of the OCP as in (7).

(7) OCP a family of markedness constraints, sharing pairs of target elements and scales of similarity and proximity

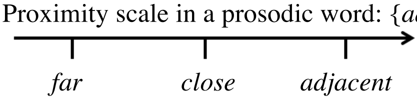
Many constraints can be classified together into constraint families such that the members of a particular family share a schema (Smolensky 1995). I propose a formalization of the OCP as a family of markedness constraints, not as a single constraint. Markedness constraints included in the same family share pairs of target elements and scales of similarity and proximity. Each constraint has a distinct requirement on target elements. For example, in the case of high tone dissimilation as in Swedish, since the targets are high tones (H), the OCP is formalized as a family of OCP-H markedness constraints targeting pairs of H tones. In the case of consonant co-occurrence restrictions e.g. Arabic (Pierrehumbert 1993; Frisch et al. 1997, 2004), the OCP is formalized as a family of OCP-C markedness constraints sharing pairs of consonants (C) as target elements.

In the constraint schema of markedness constraints composing the OCP, degrees of interactions between two scales of similarity and proximity are referred to as requirements on target elements. Therefore, in order to build the constraint schema, formalization of scales of similarity and proximity and interactions between the scales are the major concerns. Scales of similarity and proximity are formalized as stringently-defined scalar degrees. The scalar degrees are not constraints themselves, but they share a function with stringently-related constraints (Prince 1997; de Lacy 2002, 2004): encoding hierarchical relations between scalar elements. If a stringently-defined degree refers to a scalar element, it must also refer to scalar elements which is more marked than the current element that in the scale. For this reason, if stringently-defined scalar degrees are used as requirements on targets of constraints, the constraints can be freely-rankable with each other while maintaining the universal markedness hierarchy. Hierarchical implication between the degrees is achieved through harmonic bounding based on violation profiles. If a constraint referring to a scalar element is violated, all constraints referring to more marked elements are also violated. For example, in the case of Swedish, both scales of similarity and proximity are ternary: *identical* vs. *similar* vs. *distinct* for similarity in terms of tonal register of two target high tones and *adjacent* vs. *close* vs. *far* for proximity between the targets in a prosodic word. Markedness of scalar degrees relativized to the OCP is increased as shown by the arrows in (8) and (9): *identical* and *adjacent* are the most marked degrees, and *distinct* and *far* are the least marked degrees in each scale.

(8) Similarity scale with regard to tonal register: $\{identical\}_{\text{T-register}}$, $\{similar, identical\}_{\text{T-register}}$



(9) Proximity scale in a prosodic word: $\{adjacent\}_{\text{PrWd}}$, $\{close, adjacent\}_{\text{PrWd}}$



The ternary similarity scale is formalized as in (8). The stringently-defined scalar degree referring to *similar* must refer to *identical* too as $\{similar, identical\}_{\text{T-register}}$, because *identical* is more marked than *similar* in the scale. If two OCP-H markedness constraints refer to the scalar degrees as requirements on target high tones like OCP-H$_{\{identical\}\text{T-register}}$ and OCP-H$_{\{similar, identical\}\text{T-register}}$, they are freely-rankable with each other without any fixed ranking between them due to the stringency of the requirements on target elements. If OCP-H$_{\{similar, identical\}\text{T-register}}$ is violated, OCP-H$_{\{identical\}\text{T-register}}$ will also be violated. Formalization of the ternary Proximity scale shows a similar situation in (9). The stringently-defined scalar degree referring to *close* must also refer to the more marked *adjacent* as $\{close, adjacent\}_{\text{PrWd}}$. Constraints OCP-H$_{\{adjacent\}\text{PrWd}}$ and OCP-H$_{\{close, adjacent\}\text{PrWd}}$ are freely-rankable with each other for the same reason. If OCP-H$_{\{close, adjacent\}\text{PrWd}}$ is violated, OCP-H$_{\{adjacent\}\text{PrWd}}$ will also be violated. As shown in both cases, scalar degrees including all the scalar elements of a scale (e.g. $\{distinct, similar, identical\}_{\text{T-register}}$, $\{far, close, adjacent\}_{\text{PrWd}}$) are not defined, because their effects are automatically derived by other stringently-defined scalar degrees of the same scale.

In order to formalize interactions between similarity and proximity, the relationship between them in the OCP must be considered. Similarity plays a central role in OCP effects. The main function of the OCP is similarity avoidance (Frisch et al. 2004). Many languages including Akkadian, Japanese, and Arusa exhibit long-distance dissimilation which bans two identical or very similar elements regardless of their proximity within a certain domain (Suzuki 1998, Bennett 2013). In Japanese, for example, voicing of the initial obstruent of the second member of a compound shown in (10a-b) is blocked if there is a voiced obstruent anywhere in the second member as in (10c-d).

(10) a. /ori-kami/ ori-**g**ami 'paper folding'
b. /yama-tera/ yama-**d**era 'mountain temple'
c. /kami-kaze/ kami-ka<u>z</u>e *kami-**g**a<u>z</u>e 'divine wind'
d. /onna-kotoba/ onna-koto<u>b</u>a *onna-**g**oto<u>b</u>a 'feminine speech' (Suzuki 1998: 91)

Although there is a proximity domain requirement e.g. a morpheme in the Japanese case (10), long-distance dissimilation does not refer to any specific degrees of proximity in these cases. The OCP considers degrees of similarity only. In contrast, there is no dissimilation or co-occurrence restriction which bans two adjacent or close elements regardless of the degree of similarity between them. Across OCP phenomena, degrees of proximity are considered only when two target elements are similar enough. There is no OCP considering degrees of proximity only. This means that proximity plays a secondary role in the OCP.

Based on the relationship between similarity and proximity in the OCP, degrees of similarity can be requirements on target elements of the OCP, but degrees of proximity cannot. The OCP refers to degrees of proximity as requirements on targets only if it refers to interactions between similarity and proximity. Interactions between similarity and proximity are defined as one-to-one logical conjunctions of stringently-defined scalar degrees across two scales. Each conjunction consists of a scalar degree from a similarity scale and a scalar degree from a proximity scale. For example, interactions between the ternary similarity scale in (8) and the ternary proximity scale in (9) are defined as in (11). Via one-to-one logical conjunctions across the two scales, four types of interactions between them are defined.

(11) $\{identical\}_{\text{T-register}}$ & $\{adjacent\}_{\text{PrWd}}$
$\{identical\}_{\text{T-register}}$ & $\{close, adjacent\}_{\text{PrWd}}$
$\{similar, identical\}_{\text{T-register}}$ & $\{adjacent\}_{\text{PrWd}}$
$\{similar, identical\}_{\text{T-register}}$ & $\{close, adjacent\}_{\text{PrWd}}$

If target elements of the OCP are high tones as in Swedish, the OCP will be formalized as a family of OCP-H markedness constraints as in (12). Pairs of high tones meeting a requirement set in a markedness constraint are prohibited. The domains of similarity and proximity, tonal register (*T-register*) and a prosodic word (*PrWd*), are omitted for reasons of space.

(12) a. OCP-$\text{H}_{\{identical\}}$ A pair of high tones which are *identical* is prohibited.
b. OCP-$\text{H}_{\{similar,\ identical\}}$ A pair of high tones which are {*similar* or *identical*} is prohibited.
c. OCP-$\text{H}_{\{identical\}\&\{adjacent\}}$ A pair of high tones which are both *identical* and *adjacent* is prohibited.
d. OCP-$\text{H}_{\{identical\}\&\{close,\ adjacent\}}$ A pair of high tones which are both *identical* and {*close* or *adjacent*} is prohibited.
e. OCP-$\text{H}_{\{similar,\ identical\}\&\{adjacent\}}$ A pair of high tones which are both {*similar* or *identical*} and *adjacent* is prohibited.
f. OCP-$\text{H}_{\{similar,\ identical\}\&\{close,\ adjacent\}}$ A pair of high tones which are both {*similar* or *identical*} and {*close* or *adjacent*} is prohibited.

The first two OCP-H constraints in (12a-b) have requirements referring to the stringently-defined degrees of the ternary similarity scale in (8) only. If a pair of high tones meet a requirement referring to a degree of similarity, the pair is prohibited regardless of the degree of proximity within a fixed domain, a prosodic word in this case. The remaining four OCP-H constraints in (12c-f) have requirements referring to interactions between similarity and proximity in (11). Scalar degrees of similarity and proximity both are considered in banning pairs of high tones. Due to the stringency of the scalar degrees, the constraints are freely-rankable with each other. These constraints constitute a family of OCP-H constraints. In the following section, I will show how the re-formalized OCP models Swedish dissimilatory patterns which cannot be explained by the tranditional OCP.

3.2. Analysis of Swedish high tone dissimilation

For the dissimilatory patterns of Swedish, the two faithfulness constraints in (13) are considered. There are two types of repair for prohibited pairs of high tones: deletion of the second high tone, and down-stepping of the second high tone. The faithfulness constraint Max-IO(tone) bans deletion of tones. The faithfulness constraint Ident-IO(tonal register) bans changes of tonal register.

(13) a. Ident-IO(tonal register)	Given two tones T_1 and T_2, let α be tonal register of T_1 and β be any correspondent of α of T_2 in the Input-Output relation. Then α and β agree. (McCarthy and Prince 1999)
b. Max-IO(tone)	Every tone of the input has a correspondent in the output. (McCarthy and Prince 1995)

Pairs of high tones which are both *adjacent* and *identical* in (14) or both *adjacent* and *similar* in (15) are repaired by deletion of the second high tone. In the critical ranking for the repair, a markedness constraint referring to an interaction between similarity and proximity dominates faithfulness constraints: OCP-H$_{\{similar,\ identical\}\&\{adjacent\}}$ ≫ Max-IO(tone) ≫ Ident-IO(tonal register). Since the OCP-H dominates Max-IO(tone), two adjacent high tones are prohibited when they are identical or similar. Since Max-IO(tone) dominates Ident-IO(tonal register), changing the tonal register will not help in those cases. Focal high tones are always realized in Swedish, so the post-focal high tone is deleted.

(14) Pairs of high tones which are both *adjacent* and *identical*

μ μ | | /H H/	OCP-H$_{\{similar,\ identical\}\&\{adjacent\}}$	Max-IO(tone)	Ident-IO(tonal register)
a. H H	*!		
b. H H$^{\downarrow}$	*!		*
☞ c. H		*	

(15) Pairs of high tones which are both *adjacent* and *similar*

μ μ | | /H$^{\uparrow}$ H/	OCP-H$_{\{similar,\ identical\}\&\{adjacent\}}$	Max-IO(tone)	Ident-IO(tonal register)
a. H$^{\uparrow}$ H	*!		
b. H$^{\uparrow}$ H$^{\downarrow}$	*!		*
☞ c. H$^{\uparrow}$		*	

Pairs of high tones which are both *close* and *identical* are repaired by down-stepping of the second high tone. The critical ranking for the repair is OCP-H$_{\{identical\}\&\{close,\ adjacent\}}$ ≫ Max-IO(tone) ≫ Ident-IO(tonal register). Since Max-IO(tone) dominates Ident-IO(tonal register), deletion of a tone as the repair for the prohibited pairs is dispreferred as in (16c). For this reason, in the case of pairs of high tones which are both *close* and *identical*, the second high tone is down-stepped in the surface form, as in (16b).

(16) Pairs of high tones which are both *close* and *identical*

μ μ μ | | / H H/	OCP-H$_{\{identical\}\&\{close,\ adjacent\}}$	Max-IO(tone)	Ident-IO(tonal register)
a. H H	*!		
☞ b. H H$^{\downarrow}$			*
c. H		*!	

Pairs of high tones which are both *close* and *similar* or both *far* and *identical* show no tonal change. This means that in the critical rankings for them, faithfulness constraints dominate relevant OCP-H constraints. In the case of pairs of high tones which are both *close* and *similar*, MAX-IO(tone) and IDENT-IO(tonal register) dominate OCP-H$_{\{similar,\ identical\}\&\{close,\ adjacent\}}$ in (17). In the case of pairs of high tones which are both *far* and *identical*, OCP-H $_{\{similar,\ identical\}}$ is dominated by MAX-IO(tone) and IDENT-IO(tonal register) as in (18).

(17) Pairs of high tones which are both *close* and *similar*

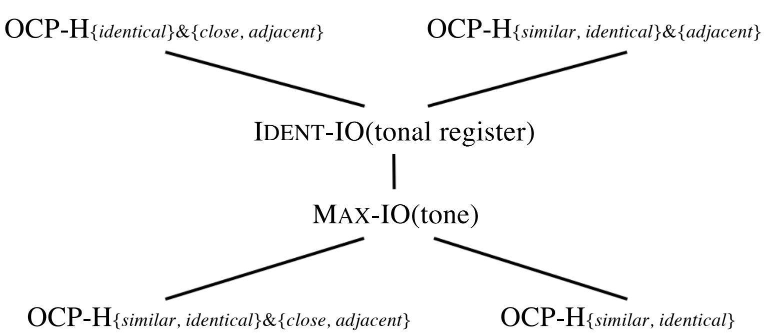
μ μ μ | | / H$^{\uparrow}$ H/	MAX-IO(tone)	IDENT-IO(tonal register)	OCP-H$_{\{similar,\ identical\}\&\{close,\ adjacent\}}$
☞ a. H$^{\uparrow}$ H			*
b. H$^{\uparrow}$ H$^{\downarrow}$		*!	
c. H	*!		

(18) Pairs of high tones which are both *far* and *identical*

μ μ μ μ | | / H H/	MAX-IO(tone)	IDENT-IO(tonal register)	OCP-H$_{\{similar,\ identical\}}$
☞ a. H H			*
b. H H$^{\downarrow}$		*!	
c. H	*!		

The ranking of the constraints for the Swedish case is represented in the Hasse diagram in Figure 2. In the Hasse diagram, we can observe that the two unviolated OCP-H constraints refer to interactions between similarity and proximity, $\{identical\}_{\text{T-register}}\&\{close,adjacent\}_{\text{PrWd}}$ and $\{similar,identical\}_{\text{T-register}}$ & $\{adjacent\}_{\text{PrWd}}$. It shows that the new formalization of the OCP considering interactions between scales of similarity and proximity can model gradient dissimilation which cannot be explained by the traditional OCP. Typological predictions made by the re-formalized OCP are promising. See Jang (to appear) for the process and results of simulations with abstract language inputs and scales using OT-Help 2.0 (Staubs et al. 2010).

Figure 2. Hasse diagram for Swedish high tone dissimilation



4. Alternatives

There are two alternatives (Suzuki 1998; Harrikari 1999) which have integrated similarity and proximity effects in the OCP. The main difference between these analyses and the proposed re-formalized OCP is that they have not provided explicit modeling of how to combine the effects of similarity and proximity.

4.1. Internal-conjunctive OCP

Harrikari (1999) proposes the internal-conjunctive OCP in order to handle the interaction effects between similarity and proximity in Swedish high tone dissimilation. The internal-conjunctive OCP includes atomic values of similarity and proximity within the constraints' formalization, as shown in (19). Similarity corresponds to tonal registers marked by α and β, and proximity corresponds to the moraic distance between two target high tones.

(19) Combined hierarchies of proximity and similarity in OCP (Harrikari 1999: 10)

μ μ		μ μ		μ μ μ		μ μ μ		μ μ μ μ		μ μ μ μ
| |	≫	| |	≫	| |	≫	| |	≫	| |	≫	| |
$*H_\alpha\ H_\alpha$		$*H_\alpha\ H_\beta$		$*H_\alpha\ \ H_\alpha$		$*H_\alpha\ \ H_\beta$		$*H_\alpha\ \ \ H_\alpha$		$*H_\alpha\ \ \ H_\beta$

The ranking in (20) between two faithfulness constraints MAX-IO(tone) and IDENT-IO(tonal register), and the internal-conjunctive OCP constraints derive all attested patterns of Swedish high tone dissimilation.

(20) Ranking for Swedish high tone dissimilation (Harrikari 1999: 12)

μ μ		μ μ				μ μ μ		
| |	≫	| |	≫	MAX-IO(tone)	≫	| |	≫	IDENT-IO(tonal register)
$*H_\alpha\ H_\alpha$		$*H_\alpha\ H_\beta$				$*H_\alpha\ \ H_\alpha$		

The major limitation of this approach is that it does not provide a systematic way of combining two scales having various structures. It is hard to anticipate the structure of interactions of more fine-grained scales of similarity or proximity, such as in the continuous similarity scale based on the Natural Class Metric in Arabic consonant co-occurrence restrictions (Pierrehumbert 1993; Frisch et al. 1997, 2004). The re-formalized OCP can handle any continuous scale. Furthermore, the internal-conjunctive OCP underpredicts the potential typological patterns compared to the new formalization of the OCP. In particular, the internal-conjunctive OCP cannot predict long-distance dissimilation which bans identical target elements regardless of degrees of proximity between them as the case of Japanese (10), due to the fixed ranking of constraints. For details, see Jang (to appear).

4.2. Generalized OCP

Suzuki (1998) introduces a constraint schema called the Generalized OCP (henceforth, GOCP), a family of OCP constraints as in (21).

(21) Generalized OCP (Suzuki 1998: 27)
*X…X: A sequence of X is prohibited.
i. Proximity: The closer the elements are the stronger the interaction.
- Hierarchy of adjacency: {*XX ≫ $*X\text{-}C_0\text{-}X$ ≫ *X-μ-X ≫ … ≫ *X-∞-X}
ii. Similarity: The more similar the elements are the stronger the interaction.
- Local conjunction of features

The major differences between the new formalization of the OCP and the GOCP are the definitions of the target scales and the link between the scales. Firstly, the GOCP constraint schema defines the proximity scale as a fixed ranking between sub-constraints reflecting each different degree of proximity between target elements. In Ainu, if two [rhotic] features have more than one intervening mora between them, no dissimilation takes place as in (22).

(22) a.	/kukoɾ ɾusuy/	kuko**n** ɾusuy		'I want to have (something)'	
b.	/kukoɾ kuɾ/	kukoɾ kuɾ	* kuko**n** kuɾ	'my husband'	(Suzuki 1998: 81)

The GOCP explains the patterns of Ainu /ɾ/ dissimilation using the ranking *[rhotic][rhotic] ≫ FAITH ≫ *[rhotic]-μ-[rhotic]. In the ranking, the fixed ranking between degrees of proximity of two target [rhotic] features is maintained. The new formalization of the OCP defines the proximity scale as a stringently-defined scalar degrees. Therefore, unlike the GOCP constraints, the OCP constraints newly formalized in this paper can be freely reranked with each other. The GOCP schema defines a similarity scale as a local conjunction of features between target elements. For instance the local conjunction of a voicing feature [voi] and an obstruent feature [-son], *[voi]-∞-[voi] & *[-son]-∞-[-son] as a GOCP constraint, accounts for the case of Japanese long-distance dissimilation of voiced obstruent in (10). As Frisch et al. (2004) point out, however, the featural conjunction approach cannot predict effects where the same degree of similarity can be achieved through different feature combinations. For example, in Arabic consonant place co-occurrence restriction, based on the Natural Class Metric the similarity of /f/ and /m/ is 0.22, and the similarity of /b/ and /w/ is also 0.22 (Pierrehumbert 1993; Frisch et al. 1997, 2004). Because they have the same degree of similarity, they show the same degree of co-occurrence restriction, but the feature combinations defining this degree of similarity are different. Local conjunction of features cannot create links between different feature combinations with the same degree of similarity. Moreover, in order to reflect a fine-grained similarity scale, more than two features would need to be conjoined under the local conjunction approach. The new formalized OCP defines scales of similarity as stringently-defined scalar degrees based on a continuous scale in the same way to formalize scales of proximity.

Secondly, the GOCP schema does not clearly indicate how to link the proximity and similarity scales. One possible way is a local conjunction between two GOCP constraints. Suzuki (1998: 41) mentions that "a GOCP constraint can be conjoined only with another GOCP constraint." However, there are no proper restrictions on local conjunction between GOCP constraints. Proximity for each conjoined constraints could be different. For example, in Latin (Suzuki 1998), lateral dissimilation shown in (23a) is blocked if there are an intervening /r/ between two target lateral consonants as in (23b).

(23) a. /sol-alis/	sol-a**r**is		'solar'		
b. /flor-alis/	flor-alis	*flor-a**r**is	'floral'		(Suzuki 1998: 102)

In order to analyze Latin lateral dissimilation and the effect of /r/-intervention as in (23), the GOCP uses a local conjunction constraint *[LIQ]~[LIQ] & *[lat]…[lat]. In the GOCP schema, X...X represents a sequence and X~X represents a strict sequence of X elements. A sequence is defined as any linear ordered pair of X's in a string, and a strict sequence is defined as any linearly ordered pair of X's which does not contain any proper subsequence of X in a string (Suzuki 1998: 43). In (23a), two /l/s are both a sequence of laterals [lat]...[lat] and a strict sequence of liquids [LIQ]~[LIQ], but in (23b) two /l/ are a sequence of laterals only due to the intervening /r/ between them. For the local conjunction constraint *[LIQ]~[LIQ] & *[lat]…[lat], two different kinds of sequences are conjoined. Following the definitions, sequences X...X and strict sequences X~X have different proximity requirements. This opens a possibility that two different degrees of proximity can be conjoined in the GOCP. Moreover, the locally-conjoined constraint shows that two different degrees of similarity can be conjoined in the GOCP too, because two liquids are similar, but not identical (as two laterals are).

Without specific restrictions on degrees of similarity and proximity conjoined together, the local conjunction between GOCP constraints would create very different typological predictions from the new formalized OCP constraints. Moreover, local conjunctions of different degrees of proximity can cause pathological predictions of dissimilatory patterns due to the domain issue. The domain for local conjunction is typically taken to be the smallest domain within which both of the conjoined constraints can be evaluated (Łubowicz 2002). Assuming a locally-conjoined constraint *[feature1][feature1] & *[feature2]-μ-[feature2] which is possible in the GOCP but not in the new formalization of the OCP, the constraint dominates *[feature1][feature1] and *[feature2]-μ-[feature2]. If a faithfulness constraint MAX is between the local conjunction constraints and the two single conjuncts as in the ranking *[feature1][feature1]&*[feature2]-μ-[feature2] ≫ MAX ≫ *[feature1][feature1], *[feature2]-μ-[feature2], pathological dissimilation patterns will be made as in (24): two identical elements *x* are not dissimilated as in (24a) since MAX dominates *[feature1][feature1], but two pairs of similar elements (*y* and *z*, and *z* and *q*) are dissimilated when the two target pairs share an element having both target features *z* as in (24b) since the local conjunction constraint domaintes MAX.

(24) a. *x* *x*
[feature1, feature2] [feature1, feature2]
b. *y* *z* *p* *q* *y* *p* *q*
[feature1] [feature1, feature2] [...] [feature2] → [feature1] ∅ [...] [feature2]
| |
μ μ

One possible way to avoid the pathological dissimilatory patterns in (24) is assuming another locally-conjoined constraint *[feature1][feature1]&*[feature2][feature2] together which dominates *[feature1][feature1]&*[feature2]-μ-[feature2] in the ranking, but the GOCP does not guarantee implicational relationships between locally-conjoined constraints like this.

5. Conclusion

This paper has proposed a new formalization of the OCP as a family of markedness constraints in order to incorporate various degrees of interaction between similarity and proximity observed in gradient dissimilation. Markedness constraints constituting the OCP share pairs of target elements and scales of similarity and proximity. Scales are formalized based on stringently-defined scalar degrees and their interactions are formalized as one-to-one logical conjunction of scalar degrees across the scales of similarity and proximity. Similarity is primary and proximity is secondary in the OCP. Considering the relationship of similarity and proximity, each markedness constraint of the OCP is defined as a prohibition of a pair of target elements if they show a specific degree of similarity or a type of interaction between similarity and proximity. The case study of Swedish shows that the proposed schema can model complex patterns of gradient dissimilation which cannot be explained by the traditional OCP.

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