Towards an optimal account of diachronic chain shifts*

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Ahn, Sang-Cheol. 2004. Towards an optimal account of diachronic chain shifts. *Studies in Phonetics, Phonology and Morphology* 10.1. 43–67. This paper reanalyzes the historical change, Grimm's law from a new perspective, employing Dispersion Theory (Flemming 1995, 1996). To this end, I will first show that Grimm's law can better be explained in terms of "push chain"[1] and the cause of the chain shift might be the heavy markedness of the voiced aspirated stops. Due to the markedness, they changed to voiced stops, not fricatives (Iverson & Salmons 1999, 2001), resulting in a push chain: i.e., [+voice, +aspirated] > [-aspirated], [+voice] > [-voice], [-voice] > [+continuant]. Second, in addition to the consideration on markedness and ease of articulation, I argue for further consideration for chain shifts, pattern evaluation, since the changes of the single segments cannot be considered separately; they are evidently parts of one great linguistic movement, obeying the "no merge" principle.[2] Third, in the explanation of each step of the changes, I will argue that local conjunction of constraints may take a crucial role in the selection of optimal outputs and eliminates the necessity of constraint re-ranking. Therefore, regardless of the historical stage, we can maintain the same constraint ranking. Moreover, as the conjoined constraint indicates the apparent trigger of the whole shift, we can avoid the so-called "chicken and egg" problem (McMahon 2000b). Furthermore, we may not face the philosophical problem of Optimality Theory (Kager 1999) since the individual constraints *Asp and *Voice take their roles in the various stages, while the conjoined constraint filters out the worst candidates. **(Kyung Hee University)**

Keywords: Diachronic chain shifts, Grimm's Law, Dispersion, Optimality Theory, Germanic, Proto-Indo-European, Pattern Evaluation, No Merge, Local Conjunction, Markedness.

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[1] There are apparent cases supporting the push chain hypothesis. Nasal vowel lowering in French, for instance, is a good example showing a push chain in that the overall shift may have been caused by the lowering of high nasal vowels (Ahn 2001).

[2] This view may originates from Jespersen (1909: 232) in describing the Great Vowel Shift in Middle English. He puts it, "the changes of the single vowels cannot be considered separately; they are evidently parts of one great linguistic movement, which affected all words containing a long vowel in ME".

1. Introduction

1.1. Grimm's law[3]

In the Proto-Indo-European consonant system, there were three types of stops, voiced aspirates, voided stops and voiceless stops, while only one fricative /s/ was existent in the phonemic inventory. During the development of Germanic languages being separated from other Indo-European, however, the stops underwent massive chain shifts, following the so-called Grimm's law.[4] (Data taken from Plyes & Algeo 1993 and Iverson & Salmons 2001).

(1) Proto-Indo-European obstruent system[5]

b^h, d^h, g^h, g^{wh}	b, d, g, g^w	p, t, k, k^w	s
[+voice, +asp]	[+voice]	[ ]	[ ]

e.g.	*b^hrāter-	'brother'		*abel-	'apple'	*pəter-	'father'
	*sed-	'sit'					
	*d^hug(h)ətēr-	'daughter'		*dent-	'tooth'	*ten-	'thin'
	*g^hed-	'get'		*genu-	'knee'	*kerd-	'heart'

Setting aside the fricative /s/, we observe two major facts. First, by Grimm's law, three types of stops formed a chain shift; [+voice, +aspirated] > [+voice, -aspirated], [+voice, -aspirated] > [-voice, -aspirated], [-voice, -aspirated] > [-voice, +continuant], as shown in the following table. (G. is used for German, while N. for Norwegian.)

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[3] Grimm's law occurred between 2000BC and 700AD when certain consonants of the Germanic languages (to which English belongs) evolved from corresponding consonants in the Proto-Indo-European (PIE, henceforth).The first stage ended around 200AD, while the second stage, between 500 and 700AD, occurred in the High German dialects of southern Germany from which modern (standard) German developed.

[4] This consonantal chain shift was first noted in the 19th century (i.e., 1818) by the Danish philologist Rasmus Christian Rask in his book *An Investigation into the Origin of the Old Norse or Icelandic Languages* (Written in Danish) and followed by Jacob Grimm's *Deutsche Grammatik* (1822: 2nd edition) (Kim 1991). Grimm's law was first named by M. Müller.

[5] In fact, the voiceless aspirated stops /p^h, t^h, k^h/ could be considered as part of the Proto-Indo-European plosives. According to Lehmann (1952: 80), these plosives were derived from the unaspirated plosive + /x/ sequence. Thus, those plosive + /x/ sequences became aspirated plosives in Indo-Iranian: e.g., IE *pltxws* > Sanskrit *pr̥thú* 'large, broad' (cf. Greek *platús*).

(2) Consonantal chain shift

TENUIS	ASPIRATA		**ASPIRATA**	MEDIA		**MEDIA**	TENUIS	
paternal	fatherly	G. väterlich N. faderlig	fraternity	brotherhood	G. Brüderschaft N. brorskap	jabloko (R.)	apple	G. Apfel N. eple
tenuous	thin	G. dünn N. tynn	thanato (phobia)	(fear of) death	G. Todes (Angst) N. dødsfal	duo	two	G. zwei[6] N. to
cordial	hearty	G. herzlich N. hjertelig	chole(lith)	gall (stone)	G. Gallen(stein) N. Galle(stein)	gelid	cold	G. kalt N. kald

Second, the labio-velar stops lost the labial articulation feature and thus merged with the velar stops.[7]

(3)

Proto-Indo-European[8]					*Germanic*		
b^h,	d^h,	g^h,	g^{wh}		b,	d,	g
p,	t,	k,	k^{wh}	>	f,	θ,	x(h)
b,	d,	g,	g^w		p,	t,	k

For instance, Gothic, the earliest attested Germanic dialect, permits something of a foothold toward this end. The past tense marker for weak verbs in Gothic shows up as *d, t,* or *θ* (represented as a "thorn" *þ*) illustrated in the following data (King 1969: 159).[9]

(4)

Infinitive	*Past sing.*	*Past part.*	*Gloss*
salbon	salboda	salboþs	'to anoint'
haban	habaida	habaiþs	'to have'
bugjan	bauhta	bauhts	'to buy'
waurkjan	waurhta	waurhts	'to effect'
þaurban	þaurfta	þayrfts	'to need'

[6] Proto-Germanic /t/ was changed to /ts/ (<z> orthographically) and /s/ (orthographically <ss>, when followed by a vowel) in German due to the so-called Second/High German Shift in the 8th century. This change began in the south and spread to the north (Pyles & Algeo 1993: 93). Therefore, the English words, *tongue, ten, eat, water*, etc. have the German correspondents, *Zunge, Zen, essen, wasser*, etc.

[7] Similar simplification processes can be found in other Indo-European languages such as Slavic (Shevelov 1964).

[8] Recently, however, a number of linguists adopted a different proposal on the PIE phonemic system, known as the "Glottalic Theory" of PIE. The proposal is that the PIE series traditionally reconstructed as voiced plosives /b, d, g, g^w/ was actually an ejective series /p', t', k', k^w'/, which would at once explain why the segment /p'/ was rare or absent. Moreover, the former /p, t, k, k^w/ are interpreted as /p^h, t^h, k^h, k^{wh}/. (For further details, refer to Trask (1996: 233-235).)

[9] Spelling alternations such as *hlaifs ~ hlaiba* and *staþs ~ stada* may suggest that intervocalic /b, d, g/ had the phonetic values [β, ð, ɣ], at least in early Gothic, but comparative evidence makes it possible that they later were voiced stops (King 1969: 160).

For the Gothic data, King (1969) claims that the best way accounting for the *d~t~þ* alternation in weak verbs is to posit underlying /t/ as the marker of the past tense of weak verbs.

(5) [+obstruent, -contituant] → [-voice]
(Any noncontinuant obstruent, i.e., stop, must be voiceless.)

As intervocalic *t* normally remains [t] in Gothic (e.g., *inweitan* 'to show reverence' and *gamotan* 'to find room'), King proposes a minor rule limited to the weak verbs changing *t* > *d* in *salboda, habaida*, etc. To account for the surface forms, then, King (1969: 159-165) proposes the following rules accounting for these shifts (in addition to the minor rule *t* > *d*).

(6) a. [+obstruent] → [α voice]/____ [+obstruent, α voice]
b. [+obstruent, -voice] → [+continuant]/_____ [+obstruent, -strident]

The first rule produces /baugta/ > [baukta], while the second rule is needed to account for the *p* > *f* and *k* > *h* [x] changes in *baukta* > *bauhta*, *waurkta* > *waurhta*, *þaurpta* > *þaurfta*. And in the participles we obtain correct *bauhts, waurhts*, and *þaurfts*. (The second rule is also motivated by the alternation of *z~s* in the comparative and superative adjectival suffixes: e.g., *managiza~managists* 'more, most', *batiza~batists* 'better, best'.)

Considering the general consonantal correspondence pattern between Germanic and PIE, however, we can easily find several problems in the earlier rule-based accounts. First, as shown in the data shown above, we need to categorize the overall pattern of Grimm's law as context-free. And it is thus difficult to provide any explanatory description on these changes in traditional accounts. As a consequence, we may provide the following types of rules to account for the three steps of the changes.

(7) a. [+voice, -continuant] → [-voice]
b. [+voice, +aspirated] → [-aspirated]
c. [-voice, -aspirated] → [+continuant]

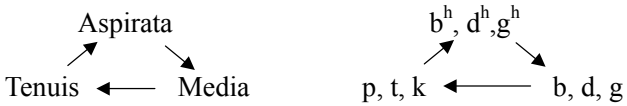
King (1969) claims that the first stage can be reconstructed to some extent as a context-free change from the Gothic evidence, while the other stages cannot be deduced by internal reconstruction. Being context-free, however, these rules do not show the uniformity of the changes.

Second, it seems impossible to explain the initial cause of the chain shift, based on internal evidence. For example, part of Grimm's law is represented as follows in Anttila (1972: 115).

(8) [stop, voiceless] → [spirant, voiceless] / [#] _____(word initially)
[accent] _____ (after accent)
⟨[spirant, dental, voiceless]⟩ [spirant, voice] / [no accent, voice] _____ [-voice]

Note, however, that those possible environments for the changes cannot provide any phonetic or phonological explanation on the cause of the change.

On the other hand, Kim (1990) proposes the following brief outline showing that the three changes form a complete circle.

(9)


As shown in the data shown above, however, the overall change was not a circular one (Plyes & Algeo 1993). For example, the plain voiceless stops changed to voiceless fricatives, rather than becoming voiced aspirated stops.[10] Therefore, as argued in Pyles & Algeo (1993), Grimm's law was not a circular process. As a consequence, Kim's proposal lacking concrete interpretation just shows a rough outline of the overall characteristics of Grimm's law.

On the other hand, Pyles & Algeo (1993: 90) argue that each set of the changes was completed before the next began. In the accompanying table, therefore, Pyles & Algeo (1993) number the steps in the order in which they happened. (The missing number (3) is the change described as Verner's law shifting voiceless fricatives to voiced ones.[11])

(10)

b^h,	d^h,	g^h	(1)	>	β,	ð,	ɤ	(5) > b, d, g
p,	t,	k	(2)	>	f,	θ,	x	(h initially)
b,	d,	g	(4)	>	p,	t,	k	

In this description, however, it is difficult to find any theoretical (or textual) evidence for the steps of the changes. Plyes & Algeo (1993) interpret the possible steps based on a kind of "no merge" principle avoiding different phonemes merged at the same location. For instance, they claim that the shift of Indo-European /b, d, g/ to Germanic /p, t, k/ must have

[10] We also note that it is often claimed that the the voiced aspirated stops underwent spirantization first becoming /β, ð, ɤ/ which later became voiced stops.

[11] /f, θ, x, s/ > /β, ð(d), ɤ, z(r)/ (/θ/ > /d/ in West Germanic, /s/ > /r/ except in Gothic, Plyes & Algeo 1993)

occurred after Indo-European /p, t, k/ had become Germanic /f, θ, x/. Otherwise, the Germanic /p, t, k/ from Indo-European /b, d, g/ would have gone to become /f, θ, x/ and we would have no native words with /p, t, k/. However, there is no explanation why these steps would have been taken in the past. To be more specific, several problems can be pointed out in this traditional account.

First of all, there was no explanation on the cause of the initial change, /b^h, d^h, g^h/ > /β, ð, ɤ/. Second, it is difficult to find a cause changing the intermediate voiced fricatives to voiced stops. For example, there seems to be no reason for the dental fricative /ð/ to become a stop /d/ since there is no possibility of taking the position of /ð/. Third, it is quite questionable to assume that the plain voiceless stops underwent spirantization, without undergoing an intermediate stage, i.e., the aspirated stops /p^h, t^h, k^h/. Unlike the proposal by Pyles & Algeo (1993), it is quite plausible to assume the intermediate stage, observing that syllable-initial aspiration is quite common in modern Germanic languages (except Icelandic showing preaspiration instead). Finally, earlier studies did not explain why the labialized stops disappeared.

Considering these problems in the earlier studies, in Section 2, I propose that the notion of markedness should be employed to trace the trigger of the whole change, while ease of articulation can also be a crucial factor accounting for subsequent changes. Then, in Section 3, I show that an Optimality-theoretic approach employing Dispersion Theory (Flemming 1995, 1996) provides a better account on those historical changes. Here, I claim that the overall shift can be explained better in terms of pattern evaluation since all the changes are related to each other, obeying the "no merge" principle. As for the disappearance of the labialised stops, however, I propose the inviolable NoComplex(place) constraint prohibiting consonants with complex place of articulation. Furthermore, I claim that the differences in the changes according to the historical stages can be accounted for with respect to local constraint conjunction, rather than different constraint ranking. In Section 4, I sum up the discussion and show further issues for future study.

1.2 Dispersion Theory

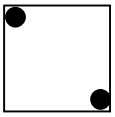
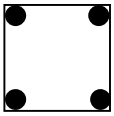
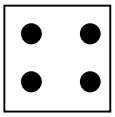
Optimality Theory (OT henceforth, McCathy & Prince 1995) is a model of constraints and constraint interactions, whereas the standard generative theory is a model of rules and derivations. In OT, we allow all possible candidate outputs and then evaluate them with a set of relevant constraints. The main analytical proposal of OT is that constraints are ranked in a hierarchy of relevance. Lower-ranked constraints can be violated in

an optimal output to respect higher-ranked constraints. An optimal output can thus minimally violate certain low-ranked constraints.

In Dispersion Theory, on the other hand, there are constraints on the well-formedness of phonological contrasts. Specifically, the selection of phonological contrasts is subject to the following three functional goals (Flemming 1995, 1996).

(11) a. Maximize the number of contrasts.
b. Maximize the distinctiveness of contrasts.
c. Minimize articulatory effort.

The possibility of incorporating these principles into OT emerges from the fact that the functional goals in (11) are in conflict with each other. The following figures illustrate the relations among the three requirements (Flemming1995, 1996).

(12) a.  b.  c. 

First, (12a) shows an inventory including only one contrast, but the contrast is maximally distinct since the two sounds are far apart from each other in the auditory space. (12b) shows the case in which we fit more sounds into the same auditory space since the sounds are closer together here. Therefore, the goals of maximizing the number of contrast and maximizing the distinctiveness of contrast conflict. Moreover, the third constraint for ease of articulation also conflicts with the constraint maximizing distinctiveness. As the sounds in the periphery of the space requires more effort than those located in the less peripheral regions, it is necessary to restrict sounds to a reduced area as shown in (12c).

The basic notions of Dispersion Theory can be incorporated in the framework of Optimality Theory in that the requirements on contrast conflict and the selection of an inventory of contrast involves achieving a balance between them (Flemming 1996, 2001). This paper employs the constraints on well-formedness of phonological contrasts within OT and shows how the historical chain shifts can be justified in terms of the phonetic naturalness and the functional role of the distinctiveness of contrasts. In this paper, therefore, it will be claimed that the final output of the obstruent system is a consequence of interactions among several phonetically natural constraints. As the well-formedness of the consonantal system cannot be evaluated in isolation, the overall result is obtained by the

pattern evaluation of the adjacent consonants.

2. On trigger and subsequent changes

2.1 Trigger

When describing shifts one usually takes one change at a time and various schemes of "**markedness**" can explain shifts. Thus, we need to take a close look at the PIE obstruent system introduced above. The following table shows four types of obstruents in PIE assumed in this paper (following Iverson & Salmons 2001).

(13) Proto-Indo-European obstruent system

Stops			Fricative
b^h, d^h, g^h, g^{wh}	b, d, g, g^w	p, t, k, k^w	s
[+voice] [+aspirated]	[+voice]		[+continuant]

Here we can note that the original stop system of Indo-European was highly marked in that it required both voice and aspiration. And this belongs to the "**weak**" point initiating a chain shift as claimed in McMahon (2000b). This assumption is supported by the observation that among the three types of obstruents in Proto-Indo-European, the voiced aspirated (or the murmured) stops were the most marked segments since they are highly unusual in the languages of the world. Therefore, the vast majority of Indo-European languages have developed less marked obstruent systems; only Sanskrit and the modern Aryan languages have retained the original highly marked system (King 1969: 193). Moreover, we can observe that only the aspirated voiced stops were subject to the Proto-Indo-European to Common Slavic change, resulting in plain voiced stops.[12] Therefore, the Proto-Indo-European voiced aspirates /b^h, d^h, g^h, g^{wh}/ became /b, d, g, g/ in Common Slavic, while the plain voiced/ voiceless stops remained intact. (The orthographic symbol "ъ" in the following table indicates a yer vowel which usually does not surface unless it is followed by another yer. Refer to Shevelov (1964) for details.)

(14)

Proto-IE	*b^h	*d^h	*g^h	*g^{wh}
Common Slavic	*b	*d	*g	*g

[12] Common Slavic was diversified into three Slavic dialects after 1000AD: East, West, and South.

Examples

Proto-IE	*neb^{h}-	*med^{h}-	*ghard^{h}-	*snoig^{wh}-
Common Slavic	*nebo	*medъ	*gordъ	*snĕgъ
Gloss	'sky'	'honey'	'city'	'snow'

As the property of aspiration was transferred to the weak vowel yer in most cases, a merge didn't occur between plain stops and aspirated ones, despite that there was no change for the plain voiceless/voiced stops. (Note, however, that the labialized velars lost their labiality.)

(15)

Proto-IE	*b	*p	*d	*t	*g	*g^{w}	*k	*k^{w}
Common Slavic	*b	*p	*d	*t	*g	*g	*k	*k

Examples : PIE *k^{w}ut- > kъto 'who'
PIE *nāg^{w}- > nagъ 'naked'

Considering these observations, therefore, we can invoke an inviolable constraint which could have triggered the whole shift.

(16) *Voiced Aspirated Stop: No voiced aspirated stops are allowed.

Due to this constraint, those voiced aspirated stops had to change to other types of consonants. From a purely conjectural point of view, however, we may consider a couple of options for the change since they could have either become plain voiced stops or undergone spirantization. Even though there is no concrete textual evidence in Modern Germanic languages, it is often assumed that they underwent spirantization (Anttilla 1972, Pyles & Algeo 1993). Here, we may consider the notion of "**ease of articulation**" for spirantization, assuming that the spirants (i.e., fricatives) require less effort than stops. This option, however, is based on a highly subjective concept (Anttila 1972: 189). If spirants are easier to pronounce than stops, it is difficult to explain why the fricatives became stops at the final stage of Grimm's law (as argued in Pyles & Algeo (1993)). As Anttila (1972: 188) admits, it is quite unusual to have voiced spirants without voiceless ones in a language that has the feature [voiceless]. Furthermore, as shown in (17), why would the Baltic Finnic speakers have replaced them with stops? (The "thorn" symbol *þ* refers to /θ/.)

(17) Consonant correspondences between Germanic (English) loans in Baltic Finnish

English (Germanic)	Finnish (Baltic Finnish)
/f/ field, Friday	/p/ pelto, perjantai
/θ/ death, (Gothic) aiþei	/t/ tauti 'sickness', äiti 'mother'
/h/ hen	/k/ kana

Therefore, it is more probable for the voiced aspirated stops to become the plain voiced stops, as shown in Iverson & Salmons (2001). In order to discourage the voiced aspirated stops not to undergo spirantization, we may need the following constraint for a constraint-based account.

(18) Ident[cont]: The [continuant] feature of the input may appear in the output.

Due to this constraint, all the stops should remain as stops. Here, we should also note that those segments with complex articulation, i.e., labio-velar stops /g^w, g^{wh}, k^w/, disappeared in an earlier stage. Thus, we need another inviolable constraint prohibiting a segment with complex articulation.

(19) *Complex(Place): Segments with complex place of articulation may not be allowed.

Employing these constraints, the following step is proposed as the initial change of Grimm's law.

(20) Step 1: b^h, d^h, g^h, g^{wh} > b, d, g, (g)

2.2 The subsequent changes

The first stage of the change now forces the original voiced stops to become the voiceless stops because the voiced stops merged with the original voiceless stops. Here we need incorporate the notion of pattern evaluation since the changes of the single segments cannot be considered separately; they are evidently parts of one great linguistic movement. Following Flemming (1996), I propose Maintain Contrast constraint avoiding possible merger, as shown below.

(21) Maintain Contrast
The phonemic contrast of the input should be maintained in the output.

Due to this constraint, the second stage of the change should have been the following shape.

(22) Step 2: b, d, g > p, t, k

Those steps 1 and 2 show that the change of the PIE obstruents was triggered and succeeded by the reduction of the marked values, i.e., [+voice, +aspirated] > [+voice], [+voice] > [-voice].

(23) Reduction of markedness: [+voice, +aspirated] > [+voice],
[+voice] > [-voice]

The next target of the chain shift is the voiceless stops /p, t, k/. Note, however, that they do not follow the general scheme of the earlier two steps of change, i.e., reduction of markedness since they had to become fricatives or aspirated stops. However, the voiceless stops could not change to voiced stops since the original slots for the voiced stops have been taken by the voiced aspirates. Thus, there are a couple of options for their changes. First, they could have change to fricatives, i.e., /p, t, k/ > /f, θ, x (h)/, as often claimed in earlier literature (King 1969, Anttila 1972, Trask 1996, Plyes & Algeo 1993, etc.). This possibility, however, is quite unnatural from a phonetic point of view in that the phonetic quality of the plain stops is quite distinct from that of the fricatives. Therefore, if allowed, it has to be an abrupt change, while most historical changes tend to be quite **gradual.** Second, in terms of pattern symmetry, there is a good reason for the voiceless fricatives not to undergo spirantization. Note that the Proto-Indo-European system had only one fricative /s/ in the phonemic inventory. Thus, if the voiceless stops underwent spirantization directly, the following asymmetric phonemic system with two similar (i.e., coronal) fricatives /θ, s/ might have appeared.

(24)

p		t	k
b		d	g
f	θ	s	x

So, the question arises: why did /t/ become the interdental fricative /θ/, changing the alveolar value of the stop? In other words, why didn't /t/ merge with /s/ during the change?

Iverson & Salmons (2001) argue that in the speech community destined to become Germanic, phonological developments began with the introduction of aspiration into the ancestral voiceless stops. They term this key innovation to the Indo-European obstruent system "Germanic

enhancement" and see it as a catalyst that induced extensive subsequent change.

(25) Germanic enhancement: Laryngeally unspecified stop → [+spread glottis][13]

As they admit, however, it is speculative to claim that Germanic enhancement was the trigger of the whole shift. Nevertheless, it is a very persuasive argument that the voiceless stops became aspirated before undergoing spirantization in the end. Thus, if we take this generalization, we can claim that the voiceless plain stops could become aspirates due to Germanic enhancement.

(26) Step 3: /p, t, k/ > /p^h, t^h, k^h/

In other words, unlike the claim in many studies like Pyles & Algeo (1993), it is more plausible to assume that the voiceless stops became aspirates for some kind of "enhancement". And we can provide at least two strong arguments for this assumption.

First of all, we might note that this generalization, Germanic enhancement still persists in the phonetic system of most modern Germanic languages including English, phonetically defining this family a part from its several sisters. For example, English and German show the distinction between aspiration in syllable initial stops vs. no aspiration in other environments, while a similar aspect is realized as preaspiration in Icelandic. But it is difficult to find such aspiration aspect in other languages like Romance or Slavic languages.

(27) { Aspiration: English, German, Swedish, Norwegian, Danish, etc.
{ Preaspiration: Icelandic
(cf. No aspiration: Dutch, Yiddish)

Here we observe that Yiddish and Dutch are different. Yiddish has been subjected to extensive Slavic influence, while Dutch (and Afrikaans) has been subjected to extensive Romance influence. Thus, they do not show aspirated stops as in Romance and Slavic languages.[14]

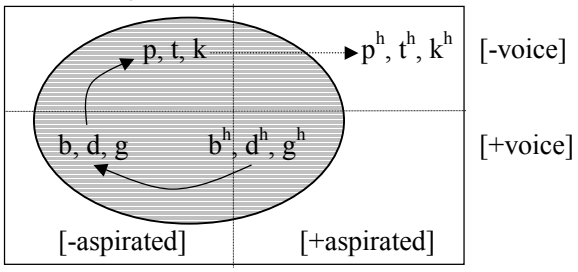
The second evidence comes from the orthographic representation in Modern English. As [f] is often transcribed as *ph* in English, while *f* in

[13] Employing Avery & Idsardi (2000)'s Dimensional Phonology, Iverson & Salmons (2001) formulate this as [ ] → GW, where GW represents Glottal Width responsible for aspiration (and glottalization, depending on the context).
[14] I am greatly indebted to Greg Iverson for this interpretation.

Romance languages, which seems to indicate that PIE /p/ went first to Proto-Germanic /ɸ/, parallel to the non-strident outputs of PIE /t, k/-spirantization. Moreover, there is some good indirect evidence from dialects of Gothic (Davis & Iverson 1993, Iverson & Salmons 1993). This orthographic evidence is somewhat indirect but it shows some clue which might show that aspiration of the voiceless stops could have occurred.

Now, adopting the view of the change /p, t, k/ > /p^h, t^h, k^h/, this process is different from the earlier steps of change, i.e., reduction of markedness, since aspirated stops are more marked than plain stops. Rather, it is a weakening process as aspirated stops are weaker than equivalent unaspirated ones, and their briefer closure durations are more susceptible to becoming incomplete. Based on the arguments made so far, we could provide the following figure showing the initial stages of the change.

(28) Initial stages of Grimm's law



As shown in the figure, the initial stage was triggered by the deaspiration of the voiced aspirates, causing a "**push-chain**" type of successive changes. The shaded area represents the earliest PIE obstruent system triggered by the principle, reduction of markedness, while the dotted arrow shows the last step, i.e., the beginning of the weakening process.

As the last step in Figure (28) shows the weakening process, this process went on further, producing spirantization. In other words, once the original voiceless stops became aspirated via Germanic Enhancement, the period of the stop occupied by the closure became less as the period occupied by the voiceless release (aspiration) became greater, assuming a more or less constant overall duration of the stops. Then, as spirants are weaker than aspirated stops, those aspirated stops undergo spirantization in a later stage.[15]

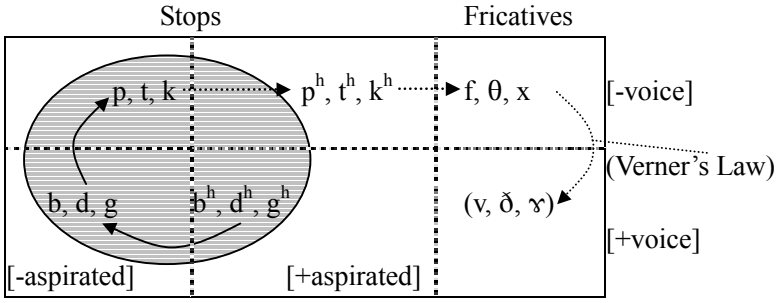
[15] According to Greg Iverson (p.c.), this is the same kind of explanation that John Ohala uses to explain why Spanish spirantizes its voiced stops medially: they are "weakened" here, with shorter duration of closure, hence the dynamics of articulation must be more precise in order to keep them as stops. The easier thing is to be less

(29) Step 4: / p^h, t^h, k^h/ > /f, θ, x/

On this issue, Iverson & Salmons (2001) claim that this is a case of "hyper-enhancement". They claim that Germanic enhancement led to a kind of hyper-enhancement, namely, the spirantization of phonetically aspirated stops. This change is akin to the later changes associated with the High German Shift or the incipient affrication of aspirated stops currently underwent in Danish. With spirantization of aspiration enhanced voiceless stops in late Indo-European/early Germanic, the original fricative class expanded considerably (and compensatorily, à la Iverson & Salmons (2001)) as the contrastive stops reduced from the three of Indo-European to the two of Germanic.

Therefore, I assume that the later stages of Grimm's law, i.e., steps 3 and 4, were the consequences of the "**weakening**" process for ease of articulation (Hooper 1976: 224).[16] We can sum up the whole process of Grimm's law as follows. (The original PIE stops (except the labio-velar stops, for convenience) are enclosed in the shaded area, while the later stages are shown in the white area.)

(30)



In this figure, the solid arrows are used for the "marked → unmarked" changes, while the dotted arrows for weakening (due to ease of articulation). Moreover, as the parentheses indicate, we can see that the later stage of weakening process went further as Verner's law.[17] Furthermore,

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precise in the closure, i.e., to let them fricativize, as Spanish does.

[16] The notion of weakening is taken from Hooper (1976) suggesting that the language-specific strength hierarchy probably specifies the paths that a segment takes in strengthening or weakening. I am thankful to Hyung-Soo Kim for suggesting this point to me.

[17] As the spirantization may have occurred in limited environments at first, i.e., post-vocalic position, providing the following constraint, we may interpret this change in terms of ease of articulation or consonantal weakening influence by adjacent vowels.

*VCh (No aspirated stops may appear after a vowel.)

we can see that Grimm's law does not show that the earlier chain shifts formed a complete circle, unlike the claim by Kim (1990).[18] Based on the discussion made so far, we can also categorize the various stages of Grimm's law as follows.

(31) Principles in Grimm's law
  a. Reduction of markedness: /b^h, d^h, g^h/ > /b, d, g/, /b, d, g/ > /p, t, k/
  b. Ease of articulation
    i. Weakening: /p, t, k/ > /p^h, t^h, k^h/, /p^h, t^h, k^h/ > /f, θ, x/
    ii. Simplification of complex articulation: /g^w, g^{wh}, k^w / > /g, g, k/

3. An OT account

3.1 Pattern evaluation

Within an OT account, however, the final step of the shift is different from those of other steps in that there was no change of the continuancy feature in the beginning stages of Grimm's law, maintaining the stop quality of the early PIE obstruents. Therefore, we need to modify the earlier constraint *Voiced Aspirated Stop in a more general shape as follows.

(32) *Asp(iration): Aspirated segments may not be allowed.

Being a more general shape, *Asp should take a major role forcing the intermediate voiceless aspirated stops to undergo spirantization.[19]

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[18] There has been no case showing a complete cycle for chain shifts (Labov 1994). For example, the Great Vowel Shift of English has caused the raising of non-high vowels but diphthongization of high vowels. In other words, the long high vowels /ī, ū/ ended up with diphthongs, rather than becoming low vowels filling the gaps vacated by the low vowel raising. Similarly, the nasal vowel lowering in French caused by the lowering of high nasal(ized) vowels has left the high nasal vowel slots empty rather than filling them up with (possible) raising of low vowels (Ahn 2001).

[19] There are, however, a couple of questions on this account. First, we may ask why *Asp constraint does not block the intermediate aspiration of the voiceless stops. The answer for this question can be found in the "**constraint ranking**": Maintain Contrast > (Ident[cont]) > *Asp. In other words, as top constraint requires that the input contrast among the stops be maintained, the voiceless stops cannot become the voiced stops, also obeying the Ident[cont]. Thus, obeying the higher ranking Ident[cont], they have only one option, i.e., aspiration, (minimally) violating the lowest ranking *Asp.

The second question is that, if ranked in the lowest, the modified *Asp does not seem to be strong enough in the earliest stage of the change, i.e., deaspiration of voiced stops, since the voiced stops could remain aspirated otherwise. Thus we may assume a different constraint ranking (or just "**re-ranking**" of constraints) for a different period (or a step) since we can locate the markedness constraint *Asp (bold-faced) at the top for the initial change, while at the bottom for the later change. As will be discussed below, however, we reject this alternative by adopting local con-

(33) Step 1 (Initiation of Grimm's law): /b^h/ > /b/

/b^h/	***Asp**	Ident[cont]	Ident[voice]	Ident[asp]
a. b^h	*!			
b. p^h	*!		*	
c. v		*!		*
d. p			*!	*
☞e. b				*

As shown in the tableau, being the trigger, *Asp takes the crucial role forcing the deaspiration of /b^h, d^h, g^h/, while Ident[voice] eliminates the competing candidates, voiceless aspirates /p^h, t^h, k^h/. Moreover, two faithfulness constraint Ident[cont] and Ident[voice] seem to be inviolable as well.

In the next step of the change, however, we need further consideration since we might get the same type of stops /b, d, g/ which remain unchanged. As mentioned in the earlier section, however, the whole chain shift was caused by the reduction of markedness and the subsequent changes were made to avoid possible merges. Thus, we need to employ the mechanism of "**pattern evaluation**" of Dispersion Theory, in which all the possible input-output correspondence candidates should be evaluated in conjunction with other groups of candidates since all the changes of chain shift are evaluated are tied up with each other. Adopting this mechanism, we employ Maintain Contrast constraint invoked earlier. Here the parentheses show the output segments (and their violation marks) from the earlier, i.e., the initial change.

(34) Step 2: /b/ > /p/ (pushed by /b^h/ > /b/)

/(b^h)b/	**Maintain Contrast**	*Asp	Ident[cont]	Ident[voice]	Ident[asp]
a. (b^h)b^h	*!	*!(*)			*
b. (b) b	*!				(*)
c. (p) b^h		*!		(*)	*
d. (p^h) v		(*)	*!	*	
☞e. (b) p				*	(*)

The newly adopted constraint Maintain Contrast is now ranked the highest to prevent possible merges between new outputs and those from the earlier process. Moreover, being violated by the optimal candidate /p/, Ident[voice] now becomes violable.

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junction of two major constraints.

3.2 Local conjunction

As we move to the next stage, however, we find a new problem in that the /p/ > /p^h/ change should violate the high ranking *Asp constraint. Therefore, we seem to need a new constraint ranking demoting *Asp, in order to allow "weakening" (i.e., minimal violation of *Asp). (Here the parentheses also show the outputs and their violation marks of the earlier changes.)

(35) Step 3: /p/ > /p^h/ (pushed by /b/ > /p/)

/(b^h b) p/	Maintain Contrast	Ident[cont]	Ident[voice]	Ident[asp]	***Asp**
a. (b^h p) b^h	*!		*(*)	*	*(*)
b. (b p) p	*!		(*)	(*)	
☞ c. (p^h b) b^h			*(*)	*	*(*)
? d. (b p) p^h			(*)	*(*)	*
e. (b p) b^h			*(*)	*(*)	*(*)

Although we demoted *Asp to the bottom, however, we get the incorrect candidate (35c) as the optimal output, rather than the correct (35d).

In order to trace the fundamental problem, therefore, we go back to the initial analysis for the triggering stage. In (32) and (33), the reason for proposing the general form of a constraint, *Asp, was to make it trigger the "marked > unmarked" /b^h/ > /b/ change in the initial stage, while allowing aspiration (i.e., weakening) in the later stage /p/ > /p^h/ by the demotion of *Asp. We should thus take a closer look at the triggering factor of the chain shift, observing that the motivation of the change was to eliminate the voiced aspirates. And those earlier voiced aspirates have never showed up in Germanic languages since the initial change. Therefore, we need to conjoin two constraints, *Voice and *Asp to prevent the voiced aspirates in Germanic. Note that the first two steps of the changes were motivated by the reduction of markedness, *Voice and *Asp are the well-motivated constraints discouraging marked values. Moreover, as will be shown below, *Voice takes an important role preventing voiced fricatives in the later stage, /p^h, t^h, k^h/ > /f, θ, x/. The local conjunction of constraints now takes a crucial role in both initial and later stages of Grimm's law.

(36) Step 1 (Initiation of Grimm's law): /b^h/ > /b/

/b^h/	***Asp&*Voice**	Ident [cont]	Ident [voice]	Indent [asp]	*Voice	*Asp
a. b^h	*!				*	*
b. p^h			*!			*
c. v		*!		*	*	
d. p			*!	*		
☞ e. b				*	*	

(37) Step 3: /p/ > /p^h/ (pushed by /b/ > /p/)

/(b^h b) p/	***Asp&*Voice**	Maintain Contrast	Ident [cont]	Ident [voice]	Ident [asp]	*Voice	*Asp
a. (b^h p) b^h	*!(*)	*		*(*)	*	*(*)	*(*)
b. (b p) p		*!		(*)	(*)	(*)	
c. (p^h b) b^h	*!			*(*)	*	*(*)	*(*)
☞ d. (b p) p^h				(*)	*(*)	(*)	*
e. (b p) b^h	*!			*(*)	*(*)	(*)	*(*)

Due to the inviolable role of the conjoined constraint, we can select the optimal candidates. In other words, by employing the local conjunction, we do not need constraint re-ranking which has been argued against by McMahon (2000b) as a "**chicken-and-egg**" problem. Moreover, in this local conjunction, we do not meet the possible logical problem argued in Kager (1999) since the role of the conjoined constraint is to eliminate the worst of the bad candidates. *Asp and *Voice play independent roles in various stages of Grimm's law but they are ranked relatively low since their violation is not fatal. Furthermore, we can explain the cause of the so-called Germanic enhancement in a more natural way.

Now when we move to the last step of Gimm's law, /p^h, t^h, k^h/ > /f, θ, x/, we face a new problem in that the noncontinuancy of the stop is to be violated in this step. As this process is pushed by the previous step /p, t, k/ > /p^h, t^h, k^h/, we need to take both process into consideration in pattern evaluation.

(38) Step 4: /p^h/ > /f/ (pushed by /p/ > /p^h/)

/(b^h b) p^h/	*Asp&*Voice	Maintain Contrast	Ident [cont]	Ident [voice]	Ident [asp]	*Voice	*Asp
a. (b^h p) p^h	*!			(*)		(*)	*(*)
? b. (b p) f			*!	(*)	(*)	(*)	
c. (b p) v			*!	*(*)	*	*(*)	
☹ d. (p^hb) p				(*)	*	(*)	(*)
e. (p b) b^h	*!			*(*)	*	*(*)	*

Although we can eliminate the wrong candidate /v/ in (38c) from the competition with the correct output /f/ (38b), we still have to eliminate the expected incorrect output /p/ in (38d). Here we might consider another local conjunction, such as *Asp&*Voiceless to escape from this difficulty. This conjunction, however, causes a more serious problem in that it should prevent the voiceless aspirates in the earlier stage as we do not adopt constraint re-ranking. Moreover, more local conjunction would make the whole grammar more complicated. Considering that this is another case of weakening, therefore, we need the following constraint enforcing voiceless stops to spirantize.

(39) *Strengthen[-voice]: Voiceless segments may not undergo strengthening in the process of a historical shift.

This constraint does not allow the voiceless aspirated stops to go back to the previous stage by undergoing strengthening.

(40) Step 4: /p^h/ > /f/ (pushed by /p/ > /p^h/)

/(b^h b) p^h/	*Asp& *Voice	*Strengthen [-voice]	Maintain Contrast	Ident [cont]	Ident [voice]	Ident [asp]	*Voice	*Asp
a. (b^h p) p^h	*!				(*)		(*)	*(*)
☞b. (b p) f				*	(*)	(*)	(*)	
c. (b p) v				*	*!(*)	*	*(*)	
d. (p^h b) p		*!			(*)	*	(*)	(*)
e. (p b) b^h	*!				*(*)	*	*(*)	*

Due to the role of the new constraint, therefore, we can get the select the correct candidate. Based on the discussion made so far, we can list the constraints and their ranking, regardless of the stages of the change.

(41) *Asp&*Voice, *Strength[-voice] >> Maintain Contrast >> Ident[cont] >> Ident[voice] >> Ident[asp] >> *Voice >>*Asp

4. Further remarks

In a similar OT approach, Petrova (2000) also employs the concept of "pattern evaluation" by Flemming (1996) but proposes the voiced stop > voiceless stop (i.e., word-initial devoicing for saliency) as the initiator of Grimm's law,[20] as illustrated below.

[20] She employs the following constraint for the initial change.
*Initial Voice Obstruent: voice obstruents are prohibited word-initially (Flemming 1996: 35).

(42) b, d, g > p, t, k
p, t, k > p^h, t^h, k^h > f, θ, x
b^h, d^h, g^h > b, d, g

Her proposal, however, entails a couple of serious problems. First, there is no phonetic motivation for the trigger except that the voiced /b, d, g/ are more marked than the voiceless counterparts /p, t, k/ and that the voiceless stops are perceptually more salient word-initially. But the voiced aspirates /b^h, d^h, g^h / are more marked than the voiced plain stops /b, d, g/. Thus, it is difficult to argue that the change of less marked stops triggered the whole shift. Moreover, it is hard to observe that Grimm's law was controlled by any specific phonological environment such as syllable. Second, adopting Petrova's proposal, only the first two changes are linked to each other, while the last change is segregated from the other two, filling the gap vacated by the initial change in a later stage. Therefore, it fails to observe the No-merge (i.e., Maintain Contrast) principle which is crucial in Dispersion Theory. Moreover, lacking phonetic/functional motivation, this account assumes a very unusual "push + drag" chain hypothesis.

(43) b, d, g ⟶ p, t, k ⟶ f, θ, x
b^h, d^h, g^h ⟶ b, d, g

Moreover, employing the concept of "pattern evaluation" (Flemming 1995), Petrova's account relies on arbitrary constraint ranking for certain constraints. For example, she employs the notion of "N way of VOT contrast(s)" to endorse the requirement for maximizing the number of contrasts, i.e., "the fewer constraints maintained, the greater the violation".

(44) 2-WAY CONSTRAST >> 3-WAY CONTRAST >> 4-WAY CONTRAST, etc.

	*Asp	3-WAY VOT CONTRAST	SPACE ≥ 1/3[21]	VOICED OBSTR	*MURMUR
a. p^h, p, b	*!			*	
☞b. p, b, b^h			*	*	*
c. p, b		*!		*	

As we can see here, the VOT contrast constraint has a gradient value, we could change the number of VOT contrast, depending on the number of

[21] This constraint is designed to meet the requirement, "Maximize auditory distinctiveness among segments". Thus, the number "3" is determined by the 3 segments of PIE.

laryngeal values in the obstruent system of the target language. In other words, the VOT contrast value "3" is determined due to the number of distinctions in laryngeal values of the PIE obstruents. In this way, depending on the number of laryngeal distinctions of a target language, we could assign any number, and end up with the notorious "chicken-and-egg" problem, one of the biggest problems in OT (McMahon 2000b). (And this account cannot be maintained when we consider an alternative proposal for Grimm's Law, i.e., the Glottalic Theory of PIE, which is described below.)

As described in Trask (1996: 233-235), a number of linguists recently adopted a different proposal on the PIE phonemic system, known as the "Glottalic Theory" of PIE. According to this proposal, the PIE series traditionally reconstructed as voiced plosives /b, d, g, g^w/ was actually an ejective series /p', t', k', k^w'/, while the former /p, t, k, k^w/ as /p^h, t^h, k^h, k^{hw}/. Therefore, their resulting system is represented as follows.

(45) p^h t^h k^h k^{wh}
b^h d^h g^h g^{wh}
p' t' k' k^w,

The advantage of this proposal can be observed in the fact that the segments /p', t', k'/ are rare or absent in Germanic languages. Moreover, this system also supports our current OT account claiming that the whole change was initiated by the principle of reduction of markedness. Thus, the deaspiration of voiced stops and the de-ejectivization of voiceless stops reflect this principle.

(46) Reduction of markedness
b^h d^h g^h g^{wh} > b d g (g)
p' t' k' k^w, > p t k (k)

Moreover, the glottalic phonemic system also provides an indirect piece of evidence for my proposal for the intermediate change in the spirantization of voiceless stops, i.e., /p, t, k/ > /p^h, t^h, k^h/ > /f, θ, x/.

(47) Ease of articulation
/p^h, t^h, k^h, k^{wh}/ > /p^h, t^h, k^h/ > /f, θ, x/

As already argued above, the later /p^h, t^h, k^h/ > /f, θ, x/ change is interpreted as a weakening process for easier articulation. Therefore, my current proposal for the trigger (i.e., reduction of markedness) and the subsequent change (i.e., ease of articulation) still hold in this Glottalic The-

ory of PIE consonant system.

5. Summary

So far, I have argued that the current proposal in conjunction with Dispersion Theory can not only show a quite plausible cause triggering Grimm's law but also provide a more explanatory (functional) interpretation of the overall chain shift. Specifically, I showed that Grimm's law can better be explained in terms of "push chain" and the possible cause of the chain shift might be the heavy markedness of the voiced aspirated stops. Due to the markedness, the voiced aspirated stops changed to plain voiced stops, not fricatives (Iverson & Salmons 1999, 2001), resulting in a push chain: i.e., [+voice, +aspirated] > [-aspirated], [+voice] > [-voice], [-voice] > [+continuant]. Thus, adopting the view that markedness or ease of articulation takes a crucial role in explaining historical sound changes (Anttila 1972), I proposed that the notion of markedness should be employed to trace the trigger of the whole change (i.e., /b^h, d^h, g^h/ > /b, d, g/, /b, d, g/ > /p, t, k/), while ease of articulation can also be a crucial factor accounting for subsequent changes (i.e., weakening in /p, t, k/ > /p^h, t^h, k^h/ > /p^h, t^h, k^h/ > /f, θ, x/). Second, in addition to the consideration on markedness and ease of articulation, I argued for further consideration for chain shifts, pattern evaluation, since the changes of the single segments cannot be considered separately; they are evidently parts of one great linguistic movement, obeying the "no merge" principle.[22] Third, in the Optimality explanation of each step of the changes, I argued that local conjunction of constraints may take a crucial role in the selection of optimal outputs. Specifically, I argued that conjoining two markedness constraints, *Asp&*Voice, can eliminate the necessity of constraint re-ranking. Therefore, regardless of the historical stage, we can maintain the same constraint ranking. Moreover, as the conjoined constraint indicates the apparent trigger of the whole shift, we can avoid the so-called "chicken and egg" problem (McMahon 2000b). Consequently, in this approach, we may not face the philosophical problem of Optimality Theory (Kager 1999) since the individual constraints *Asp and *Voice take their roles in the various stages, while the conjoined constraint filters out the worst candidates. Finally, I argued that this current approach can avoid the possible problems in a similar "pattern evaluation" approach shown in

[22] This view originates from Jespersen (1909:232) in describing the Great Vowel Shift in Middle English. He puts it, "the changes of the single vowels cannot be considered separately; they are evidently parts of one great linguistic movement, which affected all words containing a long vowel in ME".

Petrova (2000). In addition, I showed that the current account proposing the triggering constraints for the various changes still hold even if we take the so-called "Glottalic Theory" of PIE.

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