Maximally Informative Recursive Constraint Demotion: Anatolian Reduplication and its Impact on Phonological Learning

Sam Zukoff, Princeton University
szukoff@princeton.edu

The Phonetics & Experimental Phonology Laboratory, NYU
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Based on joint work with Anthony D. Yates, UCLA (Yates & Zukoff 2018a,b)

1 Introduction

- **The "Subset Principle"** of (phonological) learning (see, e.g., Prince & Tesar 2004, Hale & Reiss 2008:Ch. 2, Vaux 2009, and references therein):

> When learners are choosing between multiple possible grammars consistent with the positive evidence, they ought to select the grammar that is **most restrictive** (i.e., allows the fewest possible unseen forms).

  → Doing otherwise has the potential to *overgenerate* relative to the target language.
  - ○ No further positive evidence will ever push learner back to the more restrictive target language.
- In phonology, this reduces mainly to a preference for the higher ranking of markedness constraints than faithfulness constraints, e.g.,
  - ○ Biased Constraint Demotion (BCD; Prince & Tesar 2004)
  - ○ Low Faithfulness Constraint Demotion (LFCD; Hayes 2004)
- Most researchers agree that the phonological learning procedure should capture the Subset Principle.[1]
  - ○ i.e., little reason to think that phonological learning does not universally adhere to the Subset Principle

→ Capturing the Subset Principle is thus taken as one of the key arguments in favor of BCD and LFCD over simple Recursive Constraint Demotion (RCD; Tesar 1995, Tesar & Smolensky 1998, 2000).

- **Claim:** The diachronic development of the reduplicative systems of the Anatolian languages (Hittite and Luwian; Indo-European) provides evidence for **non-Subset Principle-compliant learning**.
  - ○ Learners learned a grammar that tolerated violations of a markedness constraint which was surface-true at an earlier stage, despite never receiving evidence that it could be violated.
  - ○ This is evidenced by the emergence of a reduplication pattern that violates the previously inviolable constraint.

→ This necessitates a change in our learning model.

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[1] Though see Vaux (2009) for an alternative view. (Thank you to Yining Nie for bringing this work to my attention.)

- **Proposal: "Maximally Informative Recursive Constraint Demotion" (MIRCD)**
  - A version of RCD (or BCD) which is biased towards winner-preferring constraints that can account for *the greatest amount of data possible*.
  - Non-Subset learning is permitted with MIRCD when there is a superset-subset relationship between the violation profiles of crucial constraints.
  - Subset-compliance and restrictiveness are maintained in all other circumstances.

Roadmap

§2 The Anatolian reduplication: evidence & analysis
§3 The reconstruction of Proto-Anatolian and its development into Hittite
§4 MIRCD for Anatolian
§5 Conclusion and the implications of MIRCD

2 Anatolian Reduplication: Evidence & Analysis

2.1 Data

- The Anatolian languages display a pattern of prefixal partial reduplication in their verbal morphology.
- The phonological shape of the reduplicant varies based on the phonological composition of the base.
  - Similar variation found in reduplication across the Indo-European languages (see, e.g., Steriade 1988, Fleischhacker 2005, Keydana 2006, Zukoff 2017).

2.1.1 Schematic patterns

- The table in (1) schematizes the range of copying patterns in Anatolian (per Yates & Zukoff 2018b; cf. Dempsey 2015, Zukoff 2017):
  - For Hittite (1a) and Luwian (1b), the two best attested Anatolian languages
  - For Proto-Anatolian (1c) (see §3 below for argumentation for this reconstruction)

(1) Anatolian partial reduplication patterns by base shape

Base Shape	a. Hittite	b. Luwian	c. Proto-Anatolian (PA)
CVX–	<u>CV</u>-CVX–	<u>CV</u>-CVX–	*<u>CV</u>-CVX–
TRVX–	<u>TRV</u>-TRVX–	<u>TV</u>-TRVX–	*<u>TV</u>-TRVX–
STVX–	*i*<u>STV</u>-STVX–	(<u>TV</u>-STVX–)	*<u>STV</u>-STVX–
VCX–	<u>VC</u>-VCX–	<u>VC</u>-VCX–	*does not exist yet*

∗ Abbreviations for segment type: *C* = any consonant, *T* = obstruent, *R* = sonorant consonant, *S* = [s], *V* = vowel, *X* = optional string of additional segments.
∗ Segments considered to be part of the reduplicant are underlined.

- Both Hittite and Luwian have C_1 copying for singleton-initial bases (<u>CV</u>-CVX–), so we can easily reconstruct this for PA.
- Hittite has cluster-copying for *obstruent+sonorant* bases (<u>TRV</u>-TRVX–), but Luwian has C_1-copying (<u>TV</u>-TRVX–). We reconstruct C_1-copying for PA based on comparative evidence.

- Hittite has cluster-copying (plus prothesis) for *s+obstruent* bases (*i*<u>STV</u>-STVX–).
    - Luwian attests forms with apparent C_2-copying; this is not a productive pattern, but rather the fossilized result of regular sound change.
    - We reconstruct cluster-copying for PA.
- Both Hittite and Luwian have VC-copying for vowel-initial bases (<u>VC</u>-VCX–).
    - PA did not allow word-initial vowels, and had no vowel-initial roots (Yates & Zukoff 2018b), so this must be an independent development in the daughter languages.
    - ⋆ **The development of this pattern is what will demonstrate that Anatolian speakers learned a non-subset language.**

2.1.2 Actual data

∗ Hitt. = Hittite, CLuw. = Cuneiform Luwian, HLuw. = Hieroglyphic Luwian

- Representative forms for CVX– reduplication:

(2) Reduplication with CVX– bases (Yates & Zukoff 2018b:207)

	Gloss	Base	Reduplicated stem	
Hitt.	'happen'	*kiš–*	*kikkiš–*	[<u>ki</u>-kːis-]
	'chant'	*mald–*	*mammalt–*	[<u>ma</u>-malt-]
	'shoot'	*šiye/a–*	*šišiye–*	[<u>si</u>-s(i)-]
	'step'	*tiye/a–*	*titti–*	[<u>ti</u>-tːi-]
	'wipe'	*warš–*	*wawarš–*	[<u>wa</u>-warsː-]
CLuw.	'take'	*la–*	*lala–*	[<u>la</u>-la-]
	'give'	*pī(ya)–*	*pipišša–*	[<u>pi</u>-pi-]
	'strike'	*dūp(a)i–*	*dūdupa–*	[<u>tuː</u>-tupa-]
HLuw.	'exalt'	*sarla–*	*sasarla–*	[<u>sa</u>-sarla-]
	'fill'	*su(wa)–*	*susu–*	[<u>su</u>-su-]
	'stand'	*ta–*	*tata–*	[<u>ta</u>-ta-]

- Exhaustive forms for TRVX– reduplication:

(3) Reduplication with TRVX– bases (Yates & Zukoff 2018b:211)

	Gloss	Base	Reduplicated stem	
Hitt.	'blow'	*par(a)i–*	*parippar(a)i–*	[<u>pri</u>-pːr(a)i-]
	'kneel'	*ḫal(a)i–*	*ḫaliḫal(a)i–*	[<u>χli</u>-χl(a)i-]
CLuw.	'carry off'	*par(a)–*	*papra–*	[<u>pa</u>-pra-]

- Exhaustive forms for STVX– reduplication:

(4) Reduplication with STVX– bases (Yates & Zukoff 2018b:213)

	Gloss	Root/Base	Reduplicated stem	
Hitt.	'become evident'	*ištu–* (/stu/)	*išdušdu-ške–*	[istu-stu-]
CLuw.	'become evident'	PA **stu–*	*dušdu-ma/i–*	[tu-stu-]
	'bind'	PA **sh$_2$(o)i–*	*ḫišḫi(ya)–*	[χi-sχi-]

- Exhaustive forms for VCX– reduplication:

(5) Reduplication with VCX– bases (Yates & Zukoff 2018b:211)

	Gloss	Base	Reduplicated stem	
Hitt.	'mount'	*ark–*	*ararkiške–*	[ar-ark-]
	'seat'	*ēš–*	*ašāš–*	[as-aːs-]
CLuw.	'wash'	*īlḫa–*	*ililḫa–*	[il-i(ː)lχa-]

2.2 Hittite Analysis

- This analysis assumes Base-Reduplicant Correspondence Theory (McCarthy & Prince 1995, 1999), with an a-templatic approach to reduplicant shape (see Spaelti 1997, Hendricks 1999, and many others).

2.2.1 CVX– bases (C$_1$-copying)

- In singleton-initial bases, the initial CV sequence is copied (any analysis will generate this easily).
- Nothing after the nucleus is copied (in this pattern, at least). This requires that a size restrictor/minimizer constraint (see Spaelti 1997, Hendricks 1999, a.o.) outranks MAX-BR:

(6) **ALIGN-ROOT-L**
Assign one violation mark * for each segment which intervenes between the left edge of the word and the left edge of the root.

(7) **MAX-BR**
Assign one violation mark * for each segment in the base without a correspondent in the reduplicant.

(8) **Hittite Ranking:** ALIGN-ROOT-L ≫ MAX-BR

- This ranking is demonstrated in (9) with the root *warš–* 'wipe'.
  - Copying one post-nuclear consonant (9b) or both post-nuclear consonants (9c) increases the number of violations of ALIGN-ROOT-L, since there are now more segments preceding the root than necessary.

(9) CVX– bases: *warš-* 'wipe' → *wa-warš-*

/RED, wars-/	ALIGN-ROOT-L	MAX-BR
a. ☞ wa-wars-	**	**
b. war-wars-	***!	*
c. wars-wars-	***!*	

2.2.2 TRVX– bases (cluster-copying)

- Given the ranking in (8), we might expect copying only a single consonant from the base-initial cluster in TRVX– bases. Since we actually get cluster-copying, we know we need another constraint:

(10) **CONTIGUITY-BR**
Assign one violation mark * if two segments which are contiguous in the base have correspondents in the reduplicant that are not contiguous.

- As long as CONTIGUITY-BR ≫ ALIGN-ROOT-L, the cluster-copying candidate (11a) will be selected over the C_1-copying candidate (11b).

(11) TRVX– bases: *pr(a)i-* 'blow' → *<u>pri</u>-pr(a)i–*[2]

/RED, prai-/	ANCHOR-L-BR	CONTIGUITY-BR	ALIGN-ROOT-L
a. ☞ <u>pri</u>-prai-			***
b. <u>pi</u>-prai-		*!	**
c. <u>ri</u>-prai-	*!		**

- The selection of the the cluster-copying candidate (11a) over a mis-anchored C_2-copying candidate (11c) demonstrates that ANCHOR-L-BR also dominates ALIGN-ROOT-L.

(12) **ANCHOR-L-BR**
Assign one violation mark * if the leftmost segment of the reduplicant does not correspond to the leftmost segment of the base.

(13) **Hittite Ranking:** ANCHOR-L-BR, CONTIGUITY-BR ≫ ALIGN-ROOT-L

2.2.3 STVX– bases (cluster-copying + prothesis)

- Hittite only attests one STVX– base, but its interpretation is quite clear:

(14) simplex *ištu–* 'become evident' → reduplicated *i<u>štu</u>-štu–*

- The initial *i-* in both the simplex form and the reduplicated form is synchronically epenthetic. This is a general process in the language:

(15) **Hittite prothesis:** Ø → [i] / #__ST

(16) Constraints involved in epenthesis
a. ***#ST**
Assign one violation mark * for each word-initial ST cluster.
b. **DEPV-IO**
Assign one violation mark * for each output vowel without an input correspondent.
c. **MAXC-IO**
Assign one violation mark * for each input consonant without an output correspondent.
d. **ONSET**
Assign one violation mark * for each onsetless syllable.

[2] This is an ablauting root. I assume that reduplicant shape is calculated essentially from the weak stem (where the [a] vowel is absent), such that there is contiquity between the [i]'s and the [r]'s.

(17) Ranking for epenthesis: *#ST, MAXC-IO ≫ DEPV-IO

- If the [i] of the simplex form were underlying, we would expect the VCX– reduplication pattern: ˣ*is-istu–*.

→ The reduplicant is just the first *stu-*, i.e. cluster copying just like TRVX– bases.[3]

- Tableau (18) demonstrates that we can derive the desired form [istu-stu-] with a ranking consistent with those already established.

(18) Reduplication of STVX– bases: /stu-/ → [istu-stu-]

/RED, stu-/	*#ST	ANCHOR-L-BR	CONTIG-BR	ONSET	DEPV-IO	ALIGN-ROOT-L
a. stu-stu-	*!					***
b. tu-stu-		*!				**
c. su-stu-			*!			**
d. *s*i*tu*-stu-			*!		*	****
e. ☞ *i*stu-stu-				*	*	****

- ○ Cluster-copying (18a) creates an impermissible initial cluster; ruled out by *#ST.
- ○ C_2-copying (18b) is mis-anchored; ruled out by ANCHOR-L-BR.
- ○ C_1-copying (18c) is discontiguous; ruled out by CONTIGUITY-BR.
- ○ (18d) copies the full cluster and epenthesizes into it. This satisfies *#ST but yields discontiguous copying, so it is also ruled out by CONTIGUITY-BR.

→ This leaves (18e), which is optimal despite its violations of ONSET and DEP, and its increased violations of ALIGN-ROOT-L.[4]

(19) **Hittite Ranking:** *#ST, ANCHOR-L-BR, CONTIG-BR ≫ DEPV-IO, ONSET, ALIGN-ROOT-L

2.2.4 VCX– bases (VC-copying)

- Vowel-initial roots/bases in Hittite show VC copying:

(20) simplex *ark–* 'mount' → reduplicated *ar-ark-isk–*

- This pattern follows completely from the ranking in (19), once we add that ONSET ≫ ALIGN-ROOT-L.

(21) VCX– bases: *ark-* 'mount' → *ar-ark-*

/RED, ark-/	ANCHOR-L-BR	CONTIG-BR	ONSET	ALIGN-ROOT-L	*PCR
a. ark-ark-			*	***!	
b. ☞ ar-ark-			*	**	*
c. ak-ark-		*!	*	**	
d. a-ark-			**!	*	
e. r-ark-	*!			*	*
f. k-ark-	*!			*	

3 The prothetic *i* must be outside of the reduplicant proper or else the desired candidate would run afoul of undominated ANCHOR-L-BR (cf. (18b) vs. (18e)).

4 Ruling out /RED, stu-/ → ˣ[is-*i*stu–] (with epenthesis into the base) is non-trivial, and may require an IR faithfulness constraint like DEPV-IR (Zukoff 2017:98, fn. 18).

- ○ Mis-anchoring (21e,f) and discontiguous copying (21c) are again ruled out by ANCHOR-L-BR and CONTIGUITY-BR, respectively.
- ○ Copying just the vowel (21d) creates an extra, fatal ONSET violation.
- → Copying one post-nuclear consonant (21b) is then preferred to copying both (21a) by ALIGN-ROOT-L.

- Tableau (21) introduces one new constraint:

(22) **NO POORLY-CUED REPETITIONS (*PCR) [$\approx$ *$C_\alpha VC_\alpha$ / _$C_{\text{[-sonorant]}}$]**
For each sequence of repeated identical consonants separated by a vowel ($C_\alpha VC_\alpha$), assign a violation * if that sequence immediately precedes an obstruent. (Zukoff 2017)

- This constraint is active in the reduplicative systems of many of the ancient Indo-European languages, in which TRVX– bases show C_1-copying but STVX– bases show a distinct copying pattern.

- The Hittite VC-VCX– pattern, specifically for VRTX– roots (i.e. VR-VRTX–), **violates *PCR**.

→ As tableau (21) shows, *PCR has to be ranked at the very bottom of the rankings.

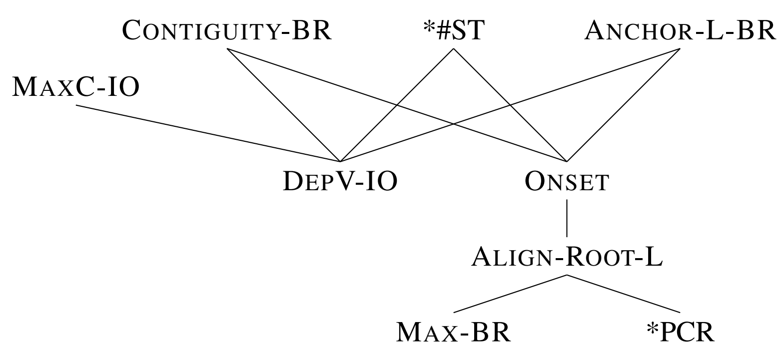
⋆ I will show in the next section that this is the exact reverse situation of Proto-Anatolian, where (like the other IE languages) *PCR must be ranked high.

⋆ How to derive this diachronic ranking reversal is the central question of this talk.

2.2.5 Hittite summary

- The rankings established in this section are summarized in the following Hasse diagram:

(23) Complete Hittite ranking (cf. Yates & Zukoff 2018b:223)



- The ranking fragment that will be of greatest interest to us is:

(24) Ranking fragment: CONTIGUITY-BR ≫ ALIGN-ROOT-L ≫ *PCR

2.3 Luwian Analysis

- Hittite and Luwian display the same surface reduplicative patterns for CVX– bases (*CV-CVX*–) and for VCX– bases (*VC-VCX*–).

- They diverge in their treatment of cluster-initial bases.
  - Luwian has the (typical IE) C_1-copying pattern for TRVX– bases: *TV-TRVX–*.
  - Luwian has verbal forms of the shape *TV-STVX–* (with apparent C_2-copying), but there are not synchronically generated (see below).

2.3.1 TRVX– bases (C_1-copying)

- To generate C_1-copying for TRVX– bases, we just need to flip the ranking of CONTIGUITY-BR relative to ALIGN-ROOT-L:

(25) **Luwian Ranking:** ALIGN-ROOT-L ≫ CONTIGUITY-BR

(26) TRVX– bases: *para-* 'carry off' → *pa-pra–* (cf. Hittite *prai-* → *pri-prai–*)

/RED, pra-/		ANCHOR-L-BR	ALIGN-ROOT-L	CONTIGUITY-BR
a.	pra-pra-		***!	
b. ☞	pa-pra-		**	*
c.	ra-pra-	*!	**	

2.3.2 VCX– bases (VC-copying)

- This ranking reversal is still consistent with the VC-VCX– pattern for vowel-initial roots. (The ranking in (27) is total.)
- Crucially, *PCR still has to rank at the bottom.

(27) VCX– bases: *īlḫa–* 'wash' → *il-ilḫa–*

/RED, ilχa-/		ANCHOR-L-BR	ONSET	ALIGN-ROOT-L	CONTIG-BR	*PCR
a.	ilχ-ilχa-		*	***!		
b. ☞	il-ilχa-		*	**		*
c.	iχ-ilχa-		*	**	*!	
d.	i-ilχa-		**!	*		
e.	l-ilχa-	*!		*		*
f.	χ-ilχa-	*!		*		

3 The Reconstruction of Proto-Anatolian and its Development into Hittite

3.1 Reconstructing PA

- The table in (28) summarizes the reduplication patterns of Hittite and Luwian. We can use these patterns as the basis for reconstructing Proto-Anatolian.

(28) Reduplication patterns of Hittite and Luwian

Base type	CVX–	TRVX–	STVX–	VCX–
Hittite	CV-CVX–	TRV-TRVX–	*i*STV-STVX–	VC-VCX–
Luwian	CV-CVX–	TV-TRVX–	(TV-STVX–)	VC-VCX–

- They agree on CV-CVX–, so we can easily reconstruct that to PA.

- While both TRV-TRVX– (cluster-copying) and TV-TRVX– (C_1-copying) are plausible reconstructions *a priori*, the fact that C_1-copying is unquestionably reconstructible for Proto-Indo-European means that it should (by Occam's Razor) be reconstructed for PA.
  - This allows us to posit only a single change for TRVX– bases: from C_1-copying to cluster-copying on the way from PA into Hittite.

- While both agree on VC-VCX–, there is good reason — both empirical and theory-internal — to say that this pattern was not yet present in PA.
  - PA doesn't have vowel-initial roots Yates & Zukoff (2018b); vowel-initial roots first come into the languages post-PA after the deletion of certain word-initial consonants (specifically, *h_1).
  - The grammar needed to generate the patterns for cluster-initial roots is inconsistent with one that generates VC-VCX–.

- Hittite and Luwian appear to disagree on STVX– bases. However, once we know the regular historical treatment of initial ST-clusters in the two languages, it becomes clear that we should reconstruct STV-STVX– (cluster-copying).

Historical development of ST-clusters in Hittite and Luwian

- Neither Hittite nor Luwian allow initial ST-clusters. Both have undergone a sound change to eliminate them:
  - Hittite shows prothesis (as discussed above).
  - Luwian shows deletion of the initial /s/:

(29) Treatment of PA #ST (cf. Melchert 1994:30–32, 2016:187–188; Yates 2014, 2016)

	PA		CLuw.			Hitt.	
a.	*$\boxed{sp}$*or–*	>	$\boxed{p}$*arritti*	'spreads'	cf.	$\boxed{išp}$*āri*	(Kloekhorst 2008:406–408)
	$\boxed{st}$(e)h₃men–*	>	$\boxed{t}$*ummān*	'ear'		$\boxed{išt}$*āmanan*	(Kloekhorst 2008:411–413)
b.	*$\boxed{sh_2}$*i(-sh₂i)–*	>	$\boxed{ḫ}$*išḫiyanti*	'bind'		$\boxed{išḫ}$*(a)i–*	
	*$\boxed{st}$*u(-stu)–*	>	$\boxed{d}$*ušdu(miš)*	'manifest'		$\boxed{išt}$*u–*	

- Both languages still tolerate ST-clusters word-internally.

(30) Treatment of PA medial ST-clusters

PA		CLuw.			Hitt.
**h₁é*$\boxed{sh_2}$*-r̥*	>	*ā*$\boxed{šḫ}$*ar(-sa)*	'blood'	cf.	*ē*$\boxed{šḫ}$*ar*
**–o*$\boxed{s\text{-}t}$*i–*	>	*lump-a*$\boxed{št}$*i–*	'regret'		*dalug-a*$\boxed{št}$*i–* 'length'
**h₁é*$\boxed{s\text{-}t}$*i*	>	*ā*$\boxed{št}$*i*	'is'		*ē*$\boxed{šz}$*i*

- Now consider again the reduplicative evidence of STVX– bases in Hittite and Luwian:

(31) Reduplication with STVX– bases (repeated from (4) above)

	Gloss	Root/Base	Reduplicated stem	
Hitt.	'become evident'	*istu–* (/stu/)	*išdušduške–*	[<u>istu</u>-stu-]
CLuw.	'become evident'	PA **stu–*	*dušduma/i–*	[<u>tu</u>-stu-]
	'bind'	PA **sh₂(o)i–*	*ḫišḫi(ya)–*	[<u>χi</u>-sχi-]

- Both the Hittite form and the Luwian forms can be seen as the reflex of PA *<u>STV</u>-STVX– derived via the application of regular sound change.

- This leads us to the reconstruction in (32):

(32) Reconstruction of Proto-Anatolian reduplication patterns

Base type	CVX–	TRVX–	STVX–	(VCX–)
Proto-Anatolian	<u>CV</u>-CVX– (C_1-copying)	<u>TV</u>-TRVX– (C_1-copying)	<u>STV</u>-STVX– (cluster-copying)	*does not exist*

3.2 Synchronic PA Analysis

- TRVX– bases show C_1-copying; this is the default behavior for cluster-initial roots.

(33) Ranking fragment that generates default C_1-copying:
ALIGN-ROOT-L ≫ CONTIGUITY-BR, MAX-BR

- STVX– bases show cluster-copying, motivated by high-ranking *PCR: it diverts the derivation away from C_1-copying just in case that would cause a *PCR violation.

(34) Ranking fragment that generates *PCR-conditioned cluster-copying:
ANCHOR-L-BR, *PCR ≫ ALIGN-ROOT-L

- The combined ranking is shown in (35). The derivations are shown in (36) and (37).

(35) **PA Ranking:** ANCHOR-L-BR, *PCR ≫ ALIGN-ROOT-L ≫ CONTIGUITY-BR, MAX-BR

(36) PA **TRVX–* → **<u>TV</u>-TRVX–* (e.g. PA **brV–* → **<u>bV</u>-brV–* > Luw. *<u>pa</u>-pra–*)

/RED, TRVX–/	ANCHOR-L-BR	*PCR	ALIGN-ROOT-L	CONTIG-BR
a. <u>TRV</u>-TRVX– (*<u>pra</u>-pra–*)			***!	
b. ☞ <u>TV</u>-TRVX– (*<u>pa</u>-pra–*)			**	*
c. <u>RV</u>-TRVX– (*<u>ra</u>-pra–*)	*!		**	

(37) PA **STVX–* → **<u>STV</u>-STVX–* (PA **stu–* → **<u>stu</u>-stu–* > Hitt. *i<u>š</u><u>du</u>šdu–*, CLuw. *dušdu–*)

/RED, STVX–/	ANCHOR-L-BR	*PCR	ALIGN-ROOT-L	CONTIG-BR
a. ☞ <u>STV</u>-STVX– (*<u>stu</u>-stu–*)			***	
b. <u>SV</u>-STVX– (*<u>su</u>-stu–*)		*!	**	*
c. <u>TV</u>-STVX– (*<u>tu</u>-stu–*)	*!		**	

3.3 Summary of Constraint Re-rankings

- The primary differences between Hittite, Luwian, and PA can be summarized by the re-ranking of three constraints: *PCR, ALIGN-ROOT-L, and CONTIGUITY-BR.

(38) Constraint rankings in Anatolian

PA	*PCR	≫	ALIGN-ROOT-L	≫	CONTIG-BR
Luwian	ALIGN-ROOT-L	≫	CONTIG-BR	≫	*PCR
Hittite	CONTIG-BR	≫	ALIGN-ROOT-L	≫	*PCR

- The set of diachronic developments can mainly be characterized by two changes in rankings.

  (i) Hittite shows a reversal of CONTIG-BR and ALIGN-ROOT-L.
  - Generates cluster-copying as default pattern for *all* cluster-initial roots, i.e., the development of the *<u>TRV</u>-TRVX–* pattern alongside the inherited *<u>STV</u>-STVX–* pattern.

  (ii) *PCR is demoted to the bottom of the ranking in Hittite and in Luwian, rendering it inactive in both languages' grammars.
  - This is what allowed for the emergence of the *<u>VC</u>-VCX–* pattern.

- This second piece raises an important question: *why (and how)* does *PCR cease to be operative between Proto-Anatolian and the Anatolian daughter languages?

→ The demotion of *PCR can be attributed to the nature of the learning input and the learning process following the Hittite- and Luwian-internal phonological changes affecting the *TRVX–* and *STVX–* bases in reduplication.
  - After the advent of vowel-initial roots, the innovative grammar that learners had arrived at because of the new learning conditions productively generates the *<u>VC</u>-VCX–* reduplication pattern for newly vowel-initial roots.

3.4 Diachronic Developments into Hittite

- The first change that takes place is the change from C_1-copying to cluster-copying for TRVX– bases.
  - (I don't claim to have much of an explanation for this.)

(39) Proto-Anatolian

/RED, prai–/	ALIGN-ROOT-L	CONTIG-BR
a. pri-prai–	***!	
b. ☞ pi-prai–	**	*

⇓ *Re-rank* ALIGN-ROOT-L & CONTIG-BR ⇓

(40) Pre-Hittite I

/RED, prai–/	CONTIG-BR	ALIGN-ROOT-L
a. ☞ pri-prai–		***
b. ✗ pi-prai–	*!	**

∗ The ✗ symbol indicates a diachronically prior stage's winner that now loses under the new constraint ranking.

- Once this change, and the associated re-ranking takes place, the learners are faced with ambiguity regarding the analysis of STVX– bases, which at all stages exhibit cluster-copying.
  - CONTIGUITY-BR now must independently rank above ALIGN-ROOT-L to account for TRV-TRVX–. This ranking is sufficient to generate STV-STVX– too.
  - While a high-ranking *PCR would motivate the right outcome too, it is no longer uniquely necessary.

→ As evidenced by the later emergence of VC-VCX–, learners resolved the indeterminacy by ranking CONTIGUITY-BR high and *PCR low, **contrary to the Subset Principle**.

(41) Proto-Anatolian

/RED, stu–/	*PCR	ALIGN-ROOT-L	CONTIG-BR
a. ☞ stu-stu–		***	
b. su-stu–	*!	**	*

⇓ *Re-rank* ALIGN-ROOT-L & CONTIG-BR (cf. (39) > (40)) ⇓

(42) Pre-Hittite I

/RED, stu–/	*PCR	CONTIG-BR	ALIGN-ROOT-L
a. ☞ stu-stu–			***
b. su-stu–	*!(?)	*!(?)	**

⇓ *Demote* *PCR ⇓

(43) Pre-Hittite II

/RED, stu–/	CONTIG-BR	ALIGN-ROOT-L	*PCR
a. ☞ *(i)*stu-stu–		***	
b. su-stu–	*!	**	*

- The importance of this ranking decision become clear when we look at the vowel-initial roots.
  - In PA, these had initial consonants, and would have reduplicated like any other singleton-initial root.
  - When they lose their initial C (subsequent to the Pre-Hittite II stage in (43)) and become V-initial, they come to reduplicate with the VC-VCX– pattern, which violates *PCR for VRTX– bases.

(44) PIE/Proto-Anatolian

/RED, h_1Vrǵ^h–/	*PCR	ALIGN-ROOT-L	CONTIG-BR
a. ☞ h_1V-h_1Vrǵ^h–		**	
b. h_1Vr-h_1Vrǵ^h–		***!	

⇓ … ⇓

(45) Pre-Hittite III (= Hittite)

/RED, ark–/	CONTIG-BR	ALIGN-ROOT-L	*PCR
a. ☞ ar-ark–		**	*
b. ark-ark–		***!	
c. ak-ark–	*!	**	

- N.B. (44a) cannot evolve into (45a) by regular sound change.

- This sequence of changes can be summarized as follows:

(46) Hittite relative chronology

Stage		**Ranking**
(I)	Proto-Anatolian	*PCR ≫ ALIGN-ROOT-L ≫ CONTIG-BR
	• *TRVX– roots: C_1-copying pattern changes to cluster-copying pattern*	
	• *Indeterminacy about ranking of *PCR vis-à-vis STVX– roots*	
(II)	Pre-Hittite I	*PCR ?? CONTIG-BR ≫ ALIGN-ROOT-L
	• **PCR is unnecessary to account for STVX– roots, so it is demoted*	
(III)	Pre-Hittite II	CONTIG-BR ≫ ALIGN-ROOT-L ≫ *PCR
	• **h_1 deletes / #_V*	
	• *Newly vowel-initial roots fed into grammar, generate VC-VCX– pattern*	
(IV)	Pre-Hittite III / Hittite	CONTIG-BR ≫ ALIGN-ROOT-L ≫ *PCR

4 MIRCD for Anatolian

- We are concerned with the ranking change between Pre-Hittite I (42) and Pre-Hittite II (43).
  - If learners had obeyed the Subset Principle, they should have ranked *PCR at the top of the ranking, because it is a markedness constraint with no evidence of violation.
    - This would have ultimately yielded a pattern for VRTX– bases where only the second post-nuclear consonant was copied: /VRTX-/ → ˣ[VT-VRTX–]
  - But evidently they did not obey the Subset Principle, because they ranked *PCR low.

- *Why did they do this?*
  - *PCR *lost its explanatory power* with the advent of the *TRV-TRVX–* pattern.
  - This lack of explanatory power is ultimately responsible for its complete demotion.

- We implement this logic with a revised constraint demotion algorithm: **Maximally Informative Recursive Constraint Demotion (MIRCD)**.

4.1 Maximally Informative Recursive Constraint Demotion (MIRCD)

- This type of logic is not consistent with most established procedures for phonological learning.

(47) Standard constraint demotion algorithms won't work:

a. Standard RCD installs all constraints who favor no losers (among the current support).
↛ *PCR is never violated and favors a winner, so it will be installed first.

b. Becker's (2009) version of RCD installs all constraints who favor no losers **and at least one winner** (among the current support).
↛ *PCR is never violated, so it will be installed first.

c. BCD first installs all markedness constraints who favor no losers.
↛ *PCR is a markedness constraint that is never violated, so it will be installed first.

d. LFCD first installs all non-faithfulness constraints who favor no losers.
↛ *PCR is a non-faithfulness constraint that is never violated, so it will be installed first.

- Standard error-driven weighted constraint learning models like the Gradual Learning Algorithm (GLA; Boersma 1997, Magri 2012) won't work either.
  - Weight accrued by erroneously picking a **SV-STVX*– output will be assigned to both *PCR and CONTIGUITY-BR.
  - While CONTIGUITY-BR will rise faster than *PCR (because of the TRVX– bases), *PCR will still end up higher than ALIGN-ROOT-L, which is not what we want.

- What is needed is a procedure that prefers to install constraints with *greater explanatory power*, i.e., prefers **the most winners**.

(48) MIRCD installs all constraints who favor no losers **and the most winners** among current support.
→ CONTIG-BR will favor 2 winners and no losers, while *PCR favors just one winner and no loser, so it will be installed first.

- Such a system can be described as aiming to explain observed *Winner∼Loser* pairs using the *fewest constraints possible*.[5]

- MIRCD is formalized in (49) [algorithm adapted from Becker 2009:164].

(49) Maximally Informative Recursive Constraint Demotion (MIRCD)

Given a Support *S*,
Given a set of constraints in *S*, *not-yet-ranked constraints*,
H := a new constraint hierarchy.

While *S* is not empty, repeat:

a. *current-stratum* := all the constraints in *not-yet-ranked constraints* that have (at least one W and) no L's in their column in *S*
b. ***maximally-informative-winners* := all the constraints in *current-stratum* for which no other constraint in *current-stratum* has more W's in their column in *S***
c. If *maximally-informative-winners* $\neq$ Ø,
   i. remove winner-loser pairs that are assigned a W by any constraint in *maximally-informative-winners*.
   ii. put *maximally-informative-winners* as the next stratum in *H*, and
   iii. remove *maximally-informative-winners* from *current stratum*
   iv. return *current stratum* to *not-yet-ranked constraints*

Put *not-yet-ranked constraints* as the next stratum in *H*.
Return *H*.

4.2 From Proto-Anatolian to Hittite

- The violation profile in (50) shows two candidate comparisons for the two cluster-initial base types at the stage following the change from C_1-copying to cluster-copying in TRVX– bases ("Pre-Hittite I" (42)).
- The comparisons are:
  (i) Between the winning cluster-copying candidate and the losing C_1-copying candidate
  (ii) Between the winning cluster-copying candidate and the losing "over-copying" candidate

- It will be helpful to consider the relationship between ALIGN-ROOT-L [ALIGN] and MAX-BR [MAX].
  - These derivations will assume that the base has additional copyable material after the first base vowel (specifically CCVCV– rather than just CCVX–).
- The "over-copying" candidate is the one that has copied the second syllable.
  - These incurs extra violations of ALIGN relative to the winning cluster-copying candidate.
- In addition to ALIGN and MAX, the violation profile in (50) and the tableaux that follow include the violation profile of these *Winner∼Loser* pairs w.r.t. *PCR and CONTIGUITY-BR [CNTG].

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[5] There are some conceptual similarities to Hayes' (2004) "Favour Autonomy" and "Favour Activeness" preferences in LFCD, though LFCD in total cannot capture this case.

- The violation profile in (50) represents the initial "support" after the change from PA *TV-TRVX*– to post-PA *TRV-TRVX*–.

(50) MIRCD: Initial Support

	*PCR	CNTG	ALIGN	MAX
i. TRVCV- → TRV-TRVCV- ≻ TV-TRVCV-	e	W	L	W
ii. TRVCV- → TRV-TRVCV- ≻ TRVCV-TRVCV-	e	e	W	L
i. STVCV- → STV-STVCV- ≻ SV-STVCV-	W	W	L	W
ii. STVCV- → STV-STVCV- ≻ STVCV-STVCV-	e	e	W	L

- ∗ **W** = winning candidate does better on the constraint than the losing candidate it is being compared with.
- ∗ **L** = winning candidate does worse.
- ∗ **e** = both candidates fare the same.

- MIRCD first installs CNTG because it has only **W**'s, and the most **W**'s.
- Unlike RCD, it doesn't install *PCR, because it does not have *the most* **W**'s.

(51) MIRCD (round 1): Install *maximally-informative winner-preferrer*, i.e. CNTG

	CNTG	*PCR	ALIGN	MAX
i. TRVCV- → TRV-TRVCV- ≻ TV-TRVCV-	W	e	L	W
ii. TRVCV- → TRV-TRVCV- ≻ TRVCV-TRVCV-	e	e	W	L
i. STVCV- → STV-STVCV- ≻ SV-STVCV-	W	W	L	W
ii. STVCV- → STV-STVCV- ≻ STVCV-STVCV-	e	e	W	L

- ∗ Grayed out rows represent *Winner∼Loser* pairs removed from support by installation of CNTG.

- Among remaining support, ALIGN is the only winner-preferrer, so it gets installed.
- Again unlike RCD, MIRCD does not install PCR despite it preferring no losers.

(52) MIRCD (round 2): Install *maximally-informative winner-preferrer*, i.e. ALIGN

	CNTG	ALIGN	*PCR	MAX
i. TRVCV- → TRV-TRVCV- ≻ TV-TRVCV-	W	L	e	W
ii. TRVCV- → TRV-TRVCV- ≻ TRVCV-TRVCV-	e	W	e	L
i. STVCV- → STV-STVCV- ≻ SV-STVCV-	W	L	W	W
ii. STVCV- → STV-STVCV- ≻ STVCV-STVCV-	e	W	e	L

- All data is now explained, so *PCR (and MAX) are ranked at the bottom of the grammar.
- This is the ranking necessary to allow the later emergence of *VR-VRTX*–.

- To summarize: the change from TV-TRVX– to TRV-TRVX– saps *PCR of its explanatory power via the promotion of CONTIGUITY-BR.
- *PCR is thus thoroughly demoted by MIRCD's informativity bias.

4.3 From Proto-Anatolian to Luwian

- In the development of Hittite, *PCR's informativity is undermined when the learning data changes to include cluster-copying for TRVX– bases.
- A parallel situation obtains in the development of Luwian:
  - The categorical deletion of /s/ in initial ST-clusters removes the STV-STVX– pattern from the learning data.
  - There is no longer any data which *PCR actively prefers, so MIRCD demotes it.

(53) MIRCD for Pre-Luwian: Initial Support

	*PCR	CONTIG	ALIGN	MAX
i. TRVCV- → TV-TRVCV- ≻ TRV-TRVCV-	e	L	W	L
ii. TRVCV- → TV-TRVCV- ≻ TRVCV-TRVCV-	e	L	W	L
i. STVCV- → STV-STVCV- ≻ SV-STVCV-	W	W	L	W
ii. STVCV- → STV-STVCV- ≻ STVCV-STVCV-	e	e	W	L

∗ Grayed out rows represent *Winner∼Loser* pairs removed from support by /s/-deletion sound change.

(54) MIRCD (round 1) for Pre-Luwian: Install ALIGN

	ALIGN	*PCR	CONTIG	MAX
i. TRVCV- → TV-TRVCV- ≻ TRV-TRVCV-	W	e	L	L
ii. TRVCV- → TV-TRVCV- ≻ TRVCV-TRVCV-	W	e	L	L

- Note that standard RCD would rank *PCR high in this case too (though Becker's version would not).

5 Discussion of MIRCD

- MIRCD permits non-subset learning in *only* one very specific case: when the violation profiles of relevant constraints stand in a superset-subset relationship.
- This exists in Pre-Hittite between CNTG_{BR} and *PCR.

(55) MIRCD: Initial Support (repeated from (50))

	***PCR**	**CNTG**	ALIGN	MAX
i. TRVCV- → TRV-TRVCV- ≻ TV-TRVCV-	$\boxed{\textbf{e}}$	$\boxed{\textbf{W}}$	L	W
ii. TRVCV- → TRV-TRVCV- ≻ TRVCV-TRVCV-	**e**	**e**	W	L
i. STVCV- → STV-STVCV- ≻ SV-STVCV-	**W**	**W**	L	W
ii. STVCV- → STV-STVCV- ≻ STVCV-STVCV-	**e**	**e**	W	L

- After the change to TRV-TRVX–, *PCR explains a proper subset of the data which CNTG_{BR} explains.
- Under these conditions, *PCR fails to be installed, even though it is an unviolated markedness constraint.

- The markedness-bias of BCD — which is responsible for implementing restrictiveness via the Subset Principle — can be incorporated, but only if it is subordinated to the *informativity*-bias.
  - i.e., the preferential installation of Markedness constraints takes the *maximally-informative-winners* as its input, not the other way around.
- This shows that the adoption of MIRCD is not wholly incompatible with the mechanisms that advocate for the subset grammar, only that it overrides this mechanism in one particular case — namely, when multiple winner-preferring constraints differ in their explanatory power.

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