Reconstructing the Phonology of Proto-Indo-European Reduplication

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1 Introduction

Prefixal partial reduplication is involved in the morphological exponence of several verbal categories in Proto-Indo-European (PIE).[1] In all the daughter languages that retain this type of reduplication, single-consonant-initial roots show a prefixal reduplicant in CV. This consonant always corresponds to the base-initial consonant (C_1). The languages differ on the nature of the vowel.

(1) Example of C_1-copying reduplication to CV-initial root in Ancient Greek
√*dō-* 'give' → PERF *de-dō-* 'have given'

In (nearly) all the languages which attest *stop-sonorant* (TR) bases, those bases reduplicate by copying the base-initial consonant followed by the reduplicative vowel. The systematic differences across the attested languages arise in the behavior of bases with other types of clusters, always including *s-stop* (ST).

(2) Indo-European reduplication by cluster type

	TR bases	**ST bases**
Old Irish	C_1-copying	C_1-copying
Sanskrit	C_1-copying	C_2-copying
Gothic	C_1-copying	cluster-copying
Ancient Greek	C_1-copying	non-copying
Latin	*not attested*	infixal C_1-copying
Hittite	cluster-copying	cluster-copying

Perhaps the most commonly held view of the PIE reconstruction of this system (e.g. Rix 1992: 202–203; Kim 2020) posits a system equivalent to Gothic (and Proto-Anatolian; Yates / Zukoff 2018), where TR bases show C_1-copying, but

[1] See generally Fortson (2010: 103–104); for details and recent analyses, see Keydana (2006, 2012), Zukoff (2017a), Kim (2020). I will focus on the evidence from the perfect, but all relevant points apply equally well to present and aorist reduplication (though probably not to the intensive).

ST bases show cluster-copying, as shown in (3). ("X" indicates any number of segments, including zero.)

(3) Traditional PIE reconstruction

a. C_1-copying for TR bases: / RED, TRVX– / → [TV-TRVX–]

b. Cluster-copying for ST bases: / RED, STVX– / → [STV-STVX–]

By positing cluster-copying for ST bases in PIE, all the attested patterns can be derived via reductions ("dissimilations") from the proto-language (Kim 2020). In this paper, I will argue for a different reconstruction: "across-the-board C_1-copying" (following, e.g., Keydana 2006; Byrd 2010: 100–105; Zukoff 2017a):

(4) Alternative PIE reconstruction (to be argued for)

a. C_1-copying for TR bases: / RED, TRVX– / → [TV-TRVX–]

b. C_1-copying for ST bases: / RED, STVX– / → [SV-STVX–]

This pattern is equivalent to the one attested in Old Irish (and elsewhere). The primary evidence for this is cognate archaisms across the family that run counter to the (semi-)productive patterns represented above (Brugmann / Delbrück 1897: 40–41; see Byrd 2010: 103–104). These are shown in (5).[2]

(5) Reduplicated presents of PIE √**steh₂* 'stand'

a. Ancient Greek ἵστημι [hí-stɛ̄-mi] < Proto-Greek **si-stā-mi* (cf. perfect ἕσταλκα [é-stal-k-a])

b. Latin *sistō* ([*si-st-ō*]) (cf. perfect *stetī* [s-te-t-ī])

c. Avestan *hi-štaiti*, *vi-ša-starᵊ*

d. Old Persian *a-hi-štatā*

The fact that the Latin and Greek forms agree with each other and with the Iranian forms can only be explained if that pattern is reconstructed to Proto-Indo-European. This precludes the "dissimilation" analysis of the changes into the daughter languages, demanding a new explanation. This paper argues for a way of understanding these changes in terms of systemic diachronic changes in Optimality Theoretic (Prince / Smolensky [1993] 2004) constraint-based synchronic grammars, as follows.[3] The various changes from "across-the-board" C_1-copying to the cluster-dependent alternations of the daughter languages result from independent promotion of the same markedness constraint, with different "repairs" in the different languages.

The paper will be structured as follows. In Section 2, I will provide constraint-based analyses of the attested languages, showing that the different systems can

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[2] This data comes from the reduplicated present. It cannot be ruled out that the perfect behaved differently in PIE. Nevertheless, the arguments to be made via analysis of the perfect do not rest on the assumption of identity with the present.

[3] This approach is similar to that of Keydana (2006), though the analyses differ substantially.

be derived by minimal re-ranking of a small set of well-motivated constraints. In Section 3, I will review the internal and comparative evidence for reconstructing "across-the-board" C_1-copying, and show how viewing the problem through the lens of constraint-based grammar change avoids the conceptual problems which have heretofore advocated for the traditional reconstruction. Section 4 briefly concludes.

2 Synchronic analysis of attested IE reduplicative systems

Putting aside for the moment the infixal pattern observed in Latin, the remaining systems can each be analyzed by a ranking of the following five constraints. Two are syllable structure markedness constraints, making demands on output syllable structure: *CLUSTER (shorthanded as *CC) (6), which penalizes having consonant clusters in the reduplicant;[4] and ONSET (7), which penalizes a reduplicant that lacks an onset consonant.

(6) ***CLUSTER (*CC):** Assign a violation * for each sequence of 2 consonants in the output. (*Don't have clusters!*)

(7) **ONSET:** Assign a violation * for each onsetless syllable. (*Have an onset!*)

Two are "Base-Reduplicant" (BR) faithfulness constraints (McCarthy / Prince 1995), essentially making demands on the similarity between the base and the reduplicant: CONTIGUITY-BR (8), which requires contiguous copying from the base (i.e. no $\underline{X_1X_3}$-$X_1X_2X_3$); and ANCHOR-L-BR (9), which requires copying that begins at the left edge of the base.

(8) **CONTIGUITY-BR:** Assign one violation * for each pair of segments that are adjacent in the reduplicant but have non-adjacent correspondents in the base. (*No skipping!*)

(9) **ANCHOR-L-BR:** Assign a violation * if the segment at the left edge of the reduplicant does not stand in correspondence with the segment at the left edge of the base. (*Copy from the left edge!*)

The last, and perhaps most significant, of the constraints is the novel NO POORLY-CUED REPETITIONS constraint (abbreviated *PCR; Zukoff 2017a), a markedness constraint penalizing certain complex output sequences involving consonant repetitions, as given in (10):[5]

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[4] Strictly speaking, this and other markedness constraints will penalize the relevant structures anywhere they appear. However, if the markedness constraints rank below the relevant Input-Output (IO) faithfulness constraints, they will not have any impact outside of reduplication. These are therefore "emergence of the unmarked" effects (McCarthy / Prince 1994, 1995).

[5] A more fine-grained version of the *PCR constraint which is sensitive to the distribution of particular phonetic properties of consonants and consonant clusters is required to account for the different cluster-wise distributions of the reduplicative alternants (see Zukoff 2017a: Ch. 6). The simplified definition used here will suffice for present purposes.

(10) **NO POORLY-CUED REPETITIONS (*PCR)** [≈ $*C_\alpha VC_\alpha / \_C_{[-\text{sonorant}]}$]
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.

This constraint militates against locally repeated consonants in pre-obstruent position. That is to say, *PCR penalizes C_1-copying to ST (i.e. *s-obstruent*-initial) bases (11a), but not to TR (*stop-sonorant*-initial) bases (11b). This is the motivation for the cluster-dependent behavior differences.

(11) Repetitions and satisfaction/violation of *PCR (schematic)

	Base type	C_1-copying	Repetition	Context	Satisfied?
a.	TR	***pa*-pr*ako***	*pap*	/ _ *r* (sonorant)	✓
b.	ST	***sa*-st*ako***	*sas*	/ _ *t* (obstruent)	✗

With the constraints introduced, I'll now show how they can be ranked to derive the full range of attested patterns. Alongside each actual dataset, I will provide a schematized version of the pattern to clarify which differences are relevant. I will also use these schematic forms to demonstrate the rankings in tableaux.

2.1 Hittite: across-the-board cluster-copying

Hittite, as shown in (12), displays "across-the-board cluster-copying" (Zukoff 2017a: Ch. 3; Yates / Zukoff 2018). In TR bases (12a), the reduplicant copies the whole cluster. In ST bases (12b), the reduplicant also copies the whole cluster. Prothesis in ST bases is a general process in the language and not specific to reduplication. A schematic version of this pattern is shown in (13).

(12) Across-the-board cluster-copying in Hittite (cf. Dempsey 2015)

	ROOT		REDUPLICATED STEM	
a.	**TR bases → cluster-copying**			
	√*par*(*a*)*i*-	'blow'	*parip*(*p*)*ar*(*a*)*i*-	[pri-pːr(a)i-]
	√*ḫal*(*a*)*i*-	'kneel'	*ḫaliḫal*(*a*)*i*-	[χli-χl(a)i-]
b.	**ST bases → cluster-copying**			
	√*stu*-	'become evident'	*išdušduške*-	[istu-stu-]

(13) Across-the-board cluster-copying (schematic)

	Base Type	Root		Reduplicated	Red. Shape
a.	Singleton	√*mako*	→	*ma-mako*	C_1V_2
b.	Stop-sonorant	√*prako*	→	*pra-prako*	$C_1C_2V_3$
c.	*s*-obstruent	√*stako*	→	*sta-stako*	$C_1C_2V_3$

The three most viable reduplicative candidates for a TR base are given in the tableau in (14). The first, candidate (14a) [pra-prako], copies the whole cluster. The second, candidate (14b) [pa-prako], copies just the first consonant. The third, candidate (14c) [ra-prako], copies just the second consonant. The three constraints that are relevant in choosing between these options are *CC (6), which is violated by (14a) because it creates a new cluster; CONTIGUITY-BR [henceforth CONTIG] (8), which is violated by (14b) because the reduplicant "skips" the base-second [r]; and ANCHOR-L-BR [henceforth ANCHOR] (9), which is violated by (14c) because the reduplicant doesn't start with a copy of the base-initial [p]. In order for candidate (14a) to win, *CC must rank below CONTIG and ANCHOR, as shown in the tableau in (14) and the ranking in (15).[6]

(14) Generating across-the-board cluster-copying: Hittite [pri-pːr(a)i-], [istu-stu-]

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

(15) **Hittite Ranking:** CONTIGUITY-BR, ANCHOR-L-BR ≫ *CC

2.2 Old Irish (and elsewhere): across-the-board C_1-copying

The evidence from the reduplicated preterites in Old Irish is shown in (15). Old Irish displays "across-the-board C_1-copying". In TR bases (16a), the reduplicant copies just the first consonant. ST bases (16b) show the same behavior. The root-initial stops in the TR-roots undergo lenition (spirantization). This pattern is reconstructible to Pre-Greek (Zukoff 2017a: Ch. 2, 2017b), and I will argue below that it should also be reconstructed for PIE. The schematic version of this pattern is shown in (17).

(16) Old Irish reduplicated preterites (Thurneysen [1946] 1980: 424–428/§§ 687–691)

	ROOT		REDUPLICATED PRETERITE	
a.	**TR bases → C1-copying**			
	√*-glenn-*	'learn'	*-geglann*	[-ge-ɣlənn]
	√*-grenn-*	'persecute'	*-gegrann*	[-ge-ɣrənn]
	√*brag-*	'bleat'	*bebrag-*	[be-vrəɣ-]
	√*klad-*	'dig'	*cechlad-*	[ke-xləð-]
b.	**ST bases → C1-copying**			
	√*skenn-*	'fly off'	*sescann-*	[se-skənn]

(17) Across-the-board C_1-copying (schematic)

	Base Type	**Root**		**Reduplicated**	**Red. Shape**
a.	Singleton	√*mako*	→	*ma-mako*	C_1V_2
b.	Stop-sonorant	√*prako*	→	*pa-prako*	C_1V_3
c.	*s*-obstruent	√*stako*	→	*sa-stako*	C_1V_3

[6] In all IE languages, consonant clusters are allowed outside of reduplication. Therefore, MAX-IO and DEP-IO (McCarthy / Prince 1995) outrank *CC, and it is never optimal to repair the base-initial cluster. This means optimal candidates (such as (14a)) will always have at least one *CC violation.

This pattern is derived by swapping the ranking of *CC and CONTIG relative to the Hittite ranking (cf. (15)), as shown in (18). This ranking means that avoiding the extra cluster (19a) is worth doing discontiguous copying (19b).

(18) **Old Irish Ranking:** ANCHOR-L-BR, *CC ≫ CONTIGUITY-BR [to be expanded]

(19) Generating across-the-board C_1-copying: Old Irish *bebrag-*

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

This pattern also gives evidence about the ranking of *PCR (≈ $*C_\alpha VC_\alpha T$; (10)). In ST bases, the optimal C_1-copying candidate (20b) violates *PCR, because of its [sVst] sequence. Since this violation isn't shared by the other candidates, *PCR must rank below ANCHOR and *CC, as reflected in (21).

(20) Generating ST C_1-copying: Old Irish *sescann-*

		/RED, stako/	ANCHOR-L-BR	*CC	CONTIGUITY-BR	*PCR
a.		sta-stako		**!		
b.	☞	sa-stako		*	*	*
c.		ta-stako	*!	*		

(21) **Old Irish Ranking (complete):** ANCHOR-L-BR, *CC ≫ CONTIGUITY-BR, *PCR

2.3 Gothic: TR C_1-copying, ST cluster-copying

Gothic, shown in (22), demonstrates distinct behavior by cluster type. Like Old Irish, Gothic exhibits C_1-copying for TR bases (22a), which is the default. On the other hand, now like Hittite, Gothic displays cluster-copying for ST base (22b). The schematic version of this pattern is shown in (23).

(22) Class VII preterites in Gothic (Lambdin 2006: 115; see also Jasanoff 2007)

	INFINITIVE			PRETERITE		
a.	**TRVX– bases → C1-copying**					
	gretan	[greːt-an]	'to weep'	*gaigrot*	[gɛ-groːt]	(not **[grɛ-groːt])
	staldan	[stald-an]	'to possess'	*staistald*	[stɛ-stald]	(not **[sɛ-stald])
b.	**STVX– bases → cluster-copying**					
	skaidan	[skæːð-an]	'to divide'	*skaiskaiþ*	[skɛ-skæːθ]	(not **[sɛ-skæːθ])

(23) TR C_1-copying, ST cluster-copying (schematic)

	Base Type	Root		Reduplicated	Red. Shape
a.	Singleton	√*mako*	→	*ma-mako*	C_1V_2
b.	Stop-sonorant	√*prako*	→	*pa-prako*	C_1V_3
c.	*s*-obstruent	√*stako*	→	*sta-stako*	$C_1C_2V_3$ (****sa-st**ako*)

We can understand this alternation as being driven by a high ranking of *PCR (Zukoff 2017a: Ch. 4; see also Zukoff / Sandell 2015). Namely, the same ranking as Old Irish (cf. (21)), but with *PCR (and ANCHOR) above *CC:

(24) **Gothic Ranking:** *PCR, ANCHOR-L-BR ≫ *CC ≫ CONTIGUITY-BR

Since *PCR isn't relevant for TR bases, this ranking has the same effect as that of Old Irish: it prefers the C_1-copying candidate (25b) with only its low-ranked CONTIG violation. On the other hand, the equivalent C_1-copying candidate for ST bases (26b) violates *PCR. This forces the grammar to select the candidate with the next lowest-ranked violation, candidate (26a), which violates *CC. In other words, it is generally preferable to avoid a consonant cluster in the reduplicant, but this is tolerated if it avoids a pre-obstruent repetition.

(25) Generating TR C_1-copying: Gothic *gaigrot*

		/RED, prako/	*PCR	ANCHOR-L-BR	*CC	CONTIG-BR
a.		pra-prako			**!	
b.	☞	pa-prako			*	*
c.		ra-prako		*!	*	

(26) Generating ST cluster-copying alongside TR C_1-copying: Gothic *staistald*

		/RED, stako/	*PCR	ANCHOR-L-BR	*CC	CONTIG-BR
a.	☞	sta-stako			**	
b.		sa-stako	*!		*	*
c.		ta-stako		*!	*	

Note also that this mode of generating cluster-copying is distinct from that in Hittite. In Hittite, cluster-copying is motivated by a desire to have contiguous copying (high-ranked CONTIG). In Gothic, however, it is motivated by a desire to avoid pre-obstruent repetitions: copying the C_2 disrupts the repetition.

2.4 Sanskrit: TR C_1-copying, ST C_2-copying

Sanskrit perfect reduplication, given in (27), illustrates a different way of satisfying *PCR (Zukoff 2017a: Ch. 5). TR bases again show C_1-copying (27a). Like Gothic, ST bases *don't* show C_1-copying; but unlike Gothic's cluster-copying repair, Sanskrit repairs the *PCR problem by copying only C_2 (27b). The schematic version of this pattern is shown in (28).

(27) Perfects to cluster-initial roots in Sanskrit (forms from Whitney 1885)

	ROOT		PERFECT TENSE	
a.	**TR roots → C1-copying**			
	√*b^h^raj-*	'shine'	*ba-b^h^rāj-a*	(not ***ra-b^h^rāj-a*)
	√*prac^h^-*	'ask'	*pa-prāc^h^-a*	(not ***ra-prāc^h^-a*)
	√*dru-*	'run'	*du-druv-ē*	(not ***ru-druv-ē*)
	√*tviṣ-*	'be stirred up'	*ti-tviṣ-e*	(not ***vi-tviṣ-ē*)
	√*sparś-*	'touch'	*pa-spṛś-ē*	(not ***sa-spṛś-ē*)
b.	**ST roots → C1-copying**			
	√*st^h^ā-*	'stand'	*ta-st^h^ā-u*	(not ***sa-st^h^ā-u*)
	√*stamb^h^-*	'prop'	*ta-stamb^h^-a*	(not ***sa-stamb^h^-a*)
	√*b^h^raj-*	'shine'	*ba-b^h^rāj-a*	(not ***ra-b^h^rāj-a*)

(28) TR C_1-copying, ST C_2-copying (schematic)

	Base Type	Root		Reduplicated	Red. Shape
a.	Singleton	√*mako*	→	*ma-mako*	C_1V_2
b.	Stop-sonorant	√*prako*	→	*pa-prako*	C_1V_3
c.	*s*-obstruent	√*stako*	→	*ta-stako*	C_2V_3 (****sa-st**ako*)

The difference between Sanskrit and Gothic can be framed as a difference in which constraint is violated under pressure from *PCR. In Gothic (24), it's *CC. In Sanskrit (29), it's ANCHOR. When *PCR is not at stake, C_1-copying (30b) remains the preferred option. When *PCR is at stake, C_1-copying (31b) is again ruled out. Since *CC outranks ANCHOR, the preferred alternative is C_2-copying (31c), which violates ANCHOR but not *CC (31a).

(29) **Sanskrit Ranking:** *PCR, *CC ≫ ANCHOR-L-BR ≫ CONTIGUITY-BR

(30) Generating TR C_1-copying: Sanskrit *pa-prāc^h^-a*

/RED, prako/	*PCR	*CC	ANCHOR-L-BR	CONTIG-BR
a. pra-prako		**!		
b. ☞ pa-prako		*		*
c. ra-prako		*	*!	

(31) Generating ST C_2-copying alongside TR C_1-copying: Sanskrit *ta-stamb^h^-a*

/RED, stako/	*PCR	*CC	ANCHOR-L-BR	CONTIG-BR
a. sta-stako		**!		
b. sa-stako	*!	*		*
c. ☞ ta-stako		*	*	

2.5 Ancient Greek: TR C_1-copying, ST non-copying

The last remaining non-infixal *PCR-avoidance strategy attested among the IE languages is to copy no consonant at all ("non-copying"), as schematized in (32), specifically (32c). This pattern is attested in Ancient Greek, as shown in (33).

(32) TR C_1-copying, ST non-copying (schematic)

	Base Type	**Root**		**Reduplicated**	**Red. Shape**
a.	Singleton	√*mako*	→	*m-e-mako*	C_1-V
b.	Stop-sonorant	√*prako*	→	*p-e-prako*	C_1-V
c.	*s*-obstruent	√*stako*	→	*e-stako*	Ø-V (**s-e-stako*)

(33) TRVX– C_1-copying, STVX– non-copying in the Ancient Greek perfect

ROOT		PERFECT TENSE		
a. **TR roots → C1-copying**				
√*kri-*	'decide'	κέκριμαι	[k-e-kri-]	(not **[e-kri-])
√*pneu-*	'breathe'	πέπνυμαι	[p-e-pnū-]	(not **[e-pnū-])
√*tla-*	'suffer, dare'	τέτληκα	[t-e-tlɛ̄-k-]	(not **[e-tlɛ̄-k-])
b. **ST roots → non-copying**				
√*stel-*	'prepare'	ἔσταλκα	[e-stal-k-]	(not **[s-e-stal-k-])
√*strat-eu-*	'wage war'	ἐστρατευμαι	[e-strat-eu-	(not **[s-e-strat-eu-])

The first thing that we'll need to do to analyze this pattern is add in ONSET (7):

(34) **ONSET:** Assign a violation * for each onsetless syllable. (*Have an onset!*)

This constraint penalizes the *PCR-driven alternative pattern, helping motivate C_1-copying in the general case (32a). We also need to make a claim about the reduplicative vowel: it must be an underlying "fixed segment", not a copy.

The patterns of reduplicant vocalism in the IE languages vacillate between two types: (i) *copy vocalism*, where the reduplicative vowel is always identical to the base vowel; vs. (ii) *fixed vocalism*, where the reduplicative vowel has a consistent value (i.e., it doesn't co-vary with the base vowel). Copy vocalism is found in Sanskrit, Anatolian (mostly), and Latin (to some extent), whereas fixed vocalism is found in Ancient Greek, Gothic, and most of the other languages.

Following Alderete et al. (1999), fixed vocalism (and consonantism) comes in two types: (i) *phonologically fixed*, where the reduplicative vowel copies the base vowel but is consistently reduced to satisfy markedness constraints (McCarthy / Prince 1994, 1995); vs. (ii) *morphologically fixed*, where the reduplicative vowel is specified in the underlying representation, and thus not a "copy" at all. Ancient Greek's ST non-copying pattern requires a morphological fixed segmentism analysis, because of the way that BR-correspondence works (see Zukoff 2017a: Ch. 2), as discussed below.

The ranking that generates the Ancient Greek pattern is the one given in (35), where ONSET ranks at the bottom. Given this ranking, ONSET enforces C_1-copying for TR bases (36b) because non-copying (36d) confers no benefit. Yet, when *PCR blocks C_1-copying for ST bases (37b), non-copying (37d) is the optimal repair because it violates only low-ranked ONSET.

(35) **Ancient Greek ranking:** *PCR, ANCHOR-L-BR, *CC ≫ ONSET[7]

(36) Generating TR C_1-copying (with morph. fixed /e/): A. Greek κέκριμαι [k-e-kri-mai]

		/RED, e, prako/	*PCR	ANCHOR-L-BR	*CC	ONSET
a.		pr-e-prako			**!	
b.	☞	p-e-prako			*	
c.		r-e-prako		*!	*	
d.		_-e-prako			*	*!

(37) Generating ST non-copying alongside TR C_1-copying: A. Greek ἔσταλκα [e-stal-k-a]

		/RED, e, stako/	*PCR	ANCHOR-L-BR	*CC	ONSET
a.		st-e-stako			**!	
b.		s-e-stako	*!		*	
c.		t-e-stako		*!	*	
d.	☞	_-e-stako			*	*

The reason we require a morphological – as opposed to phonological – fixed segmentism account is that, if the vowel were a copy (i.e. phonological fixed segmentism), winning candidate (37d) would violate ANCHOR. This violation would be equivalent to that of the C_2-copying candidate (37c), which lacks (37d)'s ONSET violation, and thus would be selected. This is illustrated in (38.i). This can be compared with the desired outcome in (38.ii), matching the analysis above, where morphological fixed segmentism allows the desired candidate to escape the ANCHOR violation. ("☹" indicates a desired winner which loses under the current ranking; "💣" indicates a desired loser which wins under the current ranking.)

(38) Anchor-L-BR violations by vocalism type

i. *Copy vocalism or phonologically-fixed vocalism*

		/RED, stako/	ANCHOR-L-BR	ONSET
a.	💣	te-stako	*	
b.	☹	e-stako	*	*!

ii. *Morphologically-fixed vocalism*

		/RED, e, stako/	ANCHOR-L-BR	ONSET
a.		t-e-stako	*!	
b.	☞	_-e-stako		*

[7] CONTIG is not relevant because the reduplicative vowel isn't a copy, meaning that, in the viable candidates, there is no multi-segment string over which it can be evaluated.

2.6 Latin infixing perfect reduplication for ST bases

The last *PCR-driven reduplicative repair we will consider in detail is infixal reduplication to ST bases in Latin (Fleischhacker 2005; DeLisi 2015). In this pattern (39), the reduplicant retains its target shape of CV, but deviates from its target position at the left edge by placing the reduplicant *after* the root-initial *s*.

(39) Latin infixing perfect reduplication to ST bases (forms from Weiss 2009: 410)

ROOT		PERFECT		
√*spond*	'promise'	*s-po-pond-ī*	(not ***so-spond-ī*)	
√*scid*	'cut'	*s-ci-cid-ī*	(not ***si-scid-ī*)	
√*st*	'stand/stop'	*s-te-t-ī*	(not ***se-st-ī*)	[but present *si-st-ō*]

Infixation is triggered by *PCR, because it again penalizes prefixal C_1-copying (e.g. ***si-scid-ī*). The primary constraint violated by infixation is ALIGN-RED-L (40), which wants the reduplicant to be as close to the left edge as possible.[8]

(40) **ALIGN-RED-L:** Assign one violation * for each segment intervening between the left edge of the reduplicant and the left edge of the word. (*Prefix the reduplicant!*)

If ALIGN-RED-L is the lowest-ranked constraint, infixation will be selected as the optimal pattern for ST bases, as in (41). That is, Latin prefers to displace the reduplicant from the left edge rather than violate *PCR (41a), mis-anchor the base (41b), or create an extra cluster (41c), all of which we observed in other IE languages. This alignment approach also correctly predicts that infixation is minimal, i.e. (41d) ≻ (41e), because ALIGN-RED-L is defined gradiently. In order for ANCHOR violations to be assessed in the necessary manner, we must identify the base of reduplication as the string to the right of the reduplicant.

(41) Infixing reduplication in Latin STVX– bases to avoid *PCR violation

		/RED, scid, ī/	*PCR	ANCHOR-L-BR	*CC	ALIGN-RED-L
a.		si-scid-ī	*!		*	
b.		ci-scid-ī		*!	*	
c.		sci-scid-ī			**!	
d.	☞	s-ci-cid-ī			*	*
e.		sc-id-id-ī			*	**!

(42) **Latin Ranking:** *PCR, ANCHOR-L-BR, *CC ≫ ALIGN-RED-L

This analysis predicts that TR roots should exhibit C_1-copying pattern, because infixation is triggered by *PCR-violating repetitions: hypothetical √*plen-* → *pe-plen-*, not ***p-le-len-*. Unfortunately, Latin doesn't have any reduplicated forms to TR roots (Cser 2009), so we can't test this prediction.

[8] Infixation inside the root also violates CONTIGUITY-IO: *Assign one violation * for each pair of segments which are adjacent in the input that have non-adjacent correspondents in the output.*

Adding ALIGN-RED-L to our constraint system requires us to consider whether it has any deleterious effects in the languages analyzed earlier. It should be clear from the current analysis that only an exceedingly *low* ranking of this constraint can trigger infixation. On the other hand, a *high* ranking of this constraint will enforce strict prefixation. This is exactly what we observe in the other languages, so we can safely assume that it is ranked high in these other languages. In future work, it is worth including this constraint in a factorial typology with the other constraints employed here to confirm that no unexpected systems can be generated by the constraint set. It is also worth mentioning that there are in fact other infixal reduplication patterns attested in the IE languages, including the desiderative in Sanskrit (Zukoff 2017a: Ch. 6) and perhaps certain preterites in Northwest Germanic (Jasanoff 2007; Zukoff 2017a: Ch. 4).

2.7 A brief look at Tocharian

Pan (2023) (drawing on Krause 1952 and Malzahn 2010) has collected the Tocharian cluster-initial reduplicated verbal forms. These patterns appear to fit well with the empirical picture which we have developed for the rest of IE. The table in (43) gives the evidence from Tocharian A. These forms all attest C_1-copying, as in Old Irish.

(43) Tocharian A cluster-initial partial reduplication

ROOT			REDUPLICATED
C-sonorant clusters			
krop(*ā*)-	'to assemble'	→	*kākropu*/*kākrupu*
prutk(*ā*)-	caus. 'to fill up'	→	*paprutku*
plant(*ā*)-	'to rejoice'	→	*pāpläntu*
mrosk(*ā*)-	'to feel disgust'	→	*māmrosku*
kärs(*ā*)-	caus. 'to make know(n)'	→	*śaśärsu*
***sp*-clusters**			
spārtw(*ā*)-	'to behave'	→	*sāspärtwu*
spärk(*ā*)-	caus. 'to destroy'	→	*ṣaṣpärku*
***st*-clusters**			
ṣtäm(*ā*)-	caus. 'to put'	→	*śaśmu*

The table in (44) gives the evidence from Tocharian B, which appears substantially more complex. Clusters ending in a sonorant all display C_1-copying, as with most of the other IE languages. ST bases where the stop is [p] appear to show C_2-copying, as in Sanskrit, while ST bases where the stop is [t] appear to show cluster-copying, as in Gothic.

(44) Tocharian B cluster-initial partial reduplication

ROOT			REDUPLICATED
C-sonorant clusters			
kraup(*ā*)-	'to assemble'	→	*kakraupau*
klutk(*ā*)-	caus. 'to make'	→	*keklyutku*
prutk(*ā*)-	caus. 'to fill up'	→	*peprutku*
plānt(*ā*)-	'to rejoice'	→	*paplāntau*
mrausk(*ā*)-	'to feel disgust'	→	*mamrauskau*
wlāwā-	'to control'	→	*wawlāwau*
***sp*-clusters**			
spārtt(*ā*)-	'to behave'	→	*paspārttau*
spārtt(*ā*)-	caus. 'to turn'	→	*peṣpirttu*
spänt(*ā*)-	caus. 'to make trust'	→	*peṣpiṃtu*
***st*-clusters**			
staukk(*ā*)-	'to swell'	→	*stastaukkauwa*
stäm(*ā*)-	caus. 'to put'	→	*śceścamoṣ*, *śeśamu*

This data seems amenable to the same sort of analysis as employed for the other IE languages, namely, that *PCR is in force in Tocharian B in prohibiting [sVsT] repetitions. But unlike the other languages we've observed, there are distinct repairs for different types of *s-stop* clusters, dependent on place. While a more thoroughgoing analysis of the language's phonotactics is necessary in order to arrive at a defensible solution, I present a sketch analysis here.

CONTIG ranks lowest, allowing *PCR-satisfying repetitions to surface with C_1-copying (just like Gothic, Sanskrit, and Ancient Greek), as demonstrated in (47). As in those languages also, *PCR diverts the derivation away from C_1-copying for ST bases, both *st* (48) and *sp* (49). However, there is now a constraint that treats the different clusters differently. I assume that this constraint is *SP (45). It penalizes only *sp*-clusters, whereas *CC (repeated with a streamlined definition in (46)) penalizes *sp*-clusters *and st*-clusters. If we rank *SP *above* ANCHOR, which in turn outranks the more general *CC, we generate distinct behavior by cluster type.

For *st*-clusters (48), the constraint *SP has no effect, so the ANCHOR violation incurred by the C_2-copying candidate (48c) is fatal. The *CC violation of the cluster-copying candidate (48a) is less costly, so this candidate is selected as the winner. On the other hand, for *sp*-clusters (49), the situation is reversed. For these roots, the cluster copying candidate (49a) now incurs an extra violation of the higher-ranked *SP constraint. This violation is more costly than the ANCHOR violation of the C_2-copying candidate (49c), so, just in case the root begins in an *sp*-cluster, C_2-copying is the optimal avoidance strategy for *PCR.

(45) ***sp:*** Assign a violation * for each *sp*-cluster in the output.

(46) ***CC:*** Assign a violation * for each cluster in the output.

(47) Generating TR C_1-copying for Tocharian B

	/RED, prako/	*PCR	*SP	ANCHOR-L-BR	*CC	CONTIG-BR
a.	pra-prako				**!	
b. ☞	pa-prako				*	*
c.	ra-prako			*!	*	

(48) Generating *st* cluster-copying for Tocharian B

	/RED, stako/	*PCR	*SP	ANCHOR-L-BR	*CC	CONTIG-BR
a. ☞	sta-stako				**	
b.	sa-stako	*!			*	*
c.	ta-stako			*!	*	

(49) Generating *sp* C_2-copying for Tocharian B

	/RED, spako/	*PCR	*SP	ANCHOR-L-BR	*CC	CONTIG-BR
a.	spa-spako		**!		**	
b.	sa-spako	*!	*		*	*
c. ☞	pa-spako		*	*	*	

(50) **Tocharian B ranking:** *PCR, *SP ≫ ANCHOR-L-BR ≫ *CC ≫ CONTIG-BR[9]

This analysis asserts that *sp*-clusters, or perhaps labials more generally, are more "marked" in the language than *st*-clusters. That is, there is no active *ST constraint, certainly not one which outranks *SP. Evidence of this sort is not known to me, so we must consider this analysis speculative. Nevertheless, it does derive the empirical distribution as it appears at this point, and it uses the exact same technology as the above analyses of the other IE languages.

3 Reconstruction of Proto-Indo-European Reduplication

We have now assembled minimally different constraint grammars for at least 6 of the IE languages.

(51) Constraint rankings

- a. Hittite: CONTIGUITY-BR, ANCHOR-L-BR ≫ *CC
- b. Old Irish: ANCHOR-L-BR, *CC ≫ CONTIGUITY-BR, *PCR
- c. Gothic: *PCR, ANCHOR-L-BR ≫ *CC ≫ CONTIGUITY-BR
- d. Sanskrit: *PCR, *CC ≫ ANCHOR-L-BR ≫ CONTIGUITY-BR
- e. Ancient Greek: *PCR, ANCHOR-L-BR, *CC ≫ ONSET
- f. Latin: *PCR, ANCHOR-L-BR, *CC ≫ ALIGN-RED-L

While there is a substantial amount of cross-linguistic variation, we can make a number of clear generalizations. First, with the exception of Hittite (and Latin, where the data is lacking), all languages exhibit prefixal C_1-copying as their

[9] As mentioned above apropos of *CC and several other of the constraints employed, *SP must be outranked by IO-faithfulness as *sp*-clusters are clearly tolerated elsewhere in the language.

default behavior for cluster-initial roots. This matches the behavior of single-consonant-initial roots. Second, while many of the languages display *PCR effects, not all do. Old Irish doesn't: *PCR is violated in C_1-copying for ST bases. The same appears to be the case for Tocharian A. From the evidence adduced earlier, *PCR does not play a role in Hittite. In fact, evidence from vowel-initial roots (Yates / Zukoff 2018) demonstrates that Hittite (and Luwian) free violates *PCR in reduplication. And third, among the languages that display *PCR effects, the specific patterns that result are all different.

Viewing these patterns as dynamic grammatical systems, we can address the question of reconstruction from a more holistic perspective. We want to reconstruct not just the forms of the proto-language, but also the *grammar* of the proto-language. When considering the reconstruction of PIE reduplication[10] from this perspective, it may be fruitful to frame the questions as in (52):

(52) a. Did PIE exhibit *PCR effects in reduplication? If so, then:
b. What was the alternative reduplication pattern induced by *PCR?

The answer that many scholars working with traditional reconstruction methods (e.g. Rix 1992: 202–203; Kim 2020) have arrived at is that PIE did exhibit *PCR effects, and that the repair was cluster-copying, as in Gothic:

(53) Traditional PIE reconstruction (repeated from (3) above)

a.	C_1-copying for TR bases:	/ RED, TRVX– / → [<u>TV</u>-TRVX–]
b.	Cluster-copying for ST bases:	/ RED, STVX– / → [<u>STV</u>-STVX–]

This reconstruction allows for all of the attested patterns to be derived from the proto-language via various reductions/"dissimilations" (cf. Kim 2020), though not by otherwise regular sound changes. If diachronic changes happen exclusively by the application of sound changes or analogical extensions, then we would be hard pressed to find any other cogent explanation. However, if we view diachronic changes as changes in constraint grammars – i.e. the increasing or decreasing priority of a given constraint – then such an explanation is available, and indeed preferable.

The position I advocate here is that the answer to (52a) is *no* (which renders (52b) moot): PIE exhibited across-the-board C_1-copying (following essentially Keydana 2006; Byrd 2010: 100–105), equivalent to Old Irish and elsewhere:

(54) Alternative PIE reconstruction to be argued for (repeated from (4) above)

a.	C_1-copying for TR bases:	/ RED, TRVX– / → [<u>TV</u>-TRVX–]
b.	C_1-copying for ST bases:	/ RED, STVX– / → [<u>SV</u>-STVX–]

[10] See McIntyre (1992); Niepokuj (1997); Keydana (2006, 2012); Zukoff (2017a); Kim (2020) for recent work on the reconstruction of reduplication in Proto-Indo-European.

I will now review evidence both from traditional internal and comparative reconstruction and from constraint-grammar comparison for this reconstruction.

3.1 Evidence from internal and comparative reconstruction

The primary evidence for reconstructing the across-the-board C_1-copying for PIE comes from archaisms. We observe *cognate archaisms* across the family that run counter to the (semi-)productive patterns examined throughout this paper. Specifically, there are a number of reflexes of a PIE reduplicated present to the root √**steh₂* 'stand':

(55) Reduplicated presents of PIE √**steh₂* 'stand' (Brugmann / Delbrück 1897: 40–41; see Byrd 2010: 103–104)

a. Ancient Greek ἵστημι [<u>hí</u>-stɛ̄-mi] < Proto-Greek *<u>*si*</u>*-stā-mi* (cf. perfect ἔσταλκα [é-stal-k-a])

b. Latin *sistō* ([<u>*si*</u>*-st-ō*]) (cf. perfect *stetī* [s-<u>te</u>-t-ī])

c. Avestan <u>*hi*</u>*-štaiti, vi-*<u>*ša*</u>*-starᵊ*

d. Old Persian *a-*<u>*hi*</u>*-štatā*

The productive pattern for ST roots in the Ancient Greek perfect (the only productive reduplicative category) is non-copying, as in ἔσταλκα [e-stal-k-a] (**[<u>s</u>-e-stal-k-a]). Yet, the unproductive reduplicated present ἵστημι [<u>h</u>-i-stɛ̄-mi] < Proto-Greek *<u>*si*</u>*-stā-mi* shows C_1-copying. So does its corresponding perfect, ἕστηκα [<u>h</u>-e-stɛ̄-k-a] < Proto-Greek *<u>*se*</u>*-stā-k-a*, which has been *retained* due to the influence of the (necessarily pre-existing) reduplicated present (Zukoff 2017a: 50–53, 2017b). This shows that Ancient Greek's *PCR effect is an *innovation*, and that a prior stage must have had across-the-board C_1-copying.

The unproductive but categorical pattern for Latin ST perfects is infixation: *stetī* [s-<u>te</u>-t-ī]. Yet, Latin attests a corresponding reduplicated present with C_1-copying: *sistō* [<u>si</u>-st-ō]. Like in Ancient Greek, present reduplication is less productive than perfect reduplication, making it highly likely that *sistō* predates *stetī.* Given that it matches the Greek form, this strongly suggests that it is a retained archaism, pointing to across-the-board C_1-copying in PIE, at least in the present.

This conclusion is further strengthened by the fact that the Latin and Greek forms agree with Iranian, but *not Sanskrit*, which has *tiṣṭʰati* [<u>ti</u>-ʂʈʰa-ti]. This should lead us to conclude that Sanskrit's C_2-copying pattern is an innovation against Proto-Indo-Iranian. (To my knowledge, C_2-copying is not attested in Iranian.) Therefore, we should treat Sanskrit *tiṣṭʰati* as an Indic innovation, not evidence for a PIE form/pattern. Thus, internal reconstruction taken together with the comparative evidence points strongly toward reconstructing C_1-copying for ST roots in PIE.

Reconstructing C_1-copying for TR roots in PIE is nearly trivial based on the evidence presented above, since all languages but Hittite show this pattern.

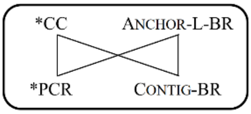
According to Yates / Zukoff (2018), Hittite's cluster-copying for TR bases is innovative against Proto-Anatolian (and Luwian). That is, Proto-Anatolian ought to be reconstructed as having the same pattern as Gothic, ST cluster-copying driven by *PCR. This makes the reconstruction in fact trivial.

3.2 Constraint ranking change and reconstruction

Reconstructing across-the-board C_1-copying precludes a "dissimilation" analysis of the changes into the daughter languages, demanding a new explanation. The evidence just presented for across-the-board C_1-copying is anything but new. It has not been determinative to this point because it never provided a feasible explanation of the changes into the daughter languages. Thinking about the problem from the perspective of constraint ranking change provides a solution.

The PIE ranking would be equivalent to Old Irish (cf. (21)):

(56) **Ranking for ATB C_1-copying in PIE:** Anchor-L-BR, *CC ≫ Contiguity-BR, *PCR



The constraint grammars of the attested systems – leaving out Hittite, which Yates / Zukoff (2018) argue to be innovative against Proto-Anatolian's Gothic-like system – are repeated in (57). When comparing these rankings to the proposed PIE ranking (equivalent to that of Old Irish), the set of changes from PIE to each respective innovative system can each be characterized in the same way: *PCR is promoted over one other constraint. This is summarized in (58).

(57) Constraint rankings of the attested languages

	~~Hittite:~~	~~Contiguity-BR, Anchor-L-BR ≫ *CC~~
a.	Old Irish:	Anchor-L-BR, *CC ≫ Contiguity-BR, *PCR
b.	Gothic:	*PCR, Anchor-L-BR ≫ *CC ≫ Contiguity-BR
c.	Sanskrit:	*PCR, *CC ≫ Anchor-L-BR ≫ Contiguity-BR
d.	Ancient Greek:	*PCR, Anchor-L-BR, *CC ≫ Onset
e.	Latin:	*PCR, Anchor-L-BR, *CC ≫ Align-Red-L

(58) Reduplicative changes and ranking changes

a.	PIE C_1-copying	→	Old Irish C_1-copying	*no change*
b.	PIE C_1-copying	→	Gothic cluster-copying	*PCR ≫ *CC
c.	PIE C_1-copying	→	Sanskrit C_2-copying	*PCR ≫ Anchor-L-BR
d.	PIE C_1-copying	→	A. Greek non-copying	*PCR ≫ Onset
e.	PIE C_1-copying	→	Latin infixation	*PCR ≫ Align-Red-L

In a certain sense, then, the changes in reduplication patterns all arise from the *same change*: increased sensitivity to the repetition avoidance constraint *PCR. But it is clear that we cannot treat this as a "shared innovation" *per se*, because the results differ so dramatically across the languages. How, then, can we fit all the pieces together? I propose that we can and should understand it in the following way.

During the stage of PIE itself, *PCR was still not strong enough to condition large-scale categorical effects, though it is possible that *PCR may have already been having limited effects in reduplication. One such proposal views certain so-called "Narten" presents with long vowels as being derived from earlier reduplicated formations (Sandell 2014, 2018), in the same way that certain long vowel preterites may have been derived later (Zukoff 2017a:Ch. 5) or perhaps in the same period:

(59) Proposed derivation for (P)IE long vowel presents/perfects

*$\underline{C_1V}$-C_1C_2… → *deletion and compensatory lengthening* → $C_1V{:}C_2$…

Evidence for such a process, which may have been more like gradient lenition than categorical phonology, might also be seen in Hittite *šip(p)and-*, which Yates / Zukoff (2018) derive from virtual **<u>si</u>-spand-* (see also Melchert 2016).

Whether it be these forces or others, the linguistic conditions inherited by the daughter languages were leading learners to become more and more sensitive to *PCR. Independently, then, each of these branches eventually promotes *PCR high enough that a repair must be initiated. However, since there are multiple ways of fixing the *PCR problem in reduplication, the pre-existing conditions did not deterministically select a single repair across the languages. Instead, each was free to "choose" which constraint *PCR would crucially outrank. (In doing so, some of the languages would have to solidify additional rankings parasitically.)

Reconstructing this sort of scenario circumvents the problem of there being no obvious phonological precursor to some of the patterns. That is to say, a change from C_1-copying to C_2-copying, for example, is unlikely to have been driven by misperception (cf., e.g., Ohala 1981). Rather, the language is forced to innovate as a response to the constraint promotion. This approach also makes sense of the fact that the languages differ somewhat in exactly which repetition types are targeted by *PCR (see Zukoff 2017a: Ch. 6 for extensive discussion). Namely, while all of these languages make a consistent distinction between TR roots and ST roots, they show substantial differences in the treatment of the other cluster types. This seems a likely state of affairs if the *PCR effects represent parallel developments driven by similar inherited conditions, but not a true shared innovation.

4 Conclusion

This paper has argued that the central issue in PIE reduplicative phonology is the behavior of *PCR, whose (simplified) definition is repeated in (60):

(60) **NO POORLY-CUED REPETITIONS (*PCR)** [≈ $*C_\alpha VC_\alpha / \_C_{[-\text{sonorant}]}$]

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.

The main takeaway from this paper is that thinking about the (P)IE reduplicative system in terms of constraints and rankings, rather than purely in terms of forms, allows us to integrate the internal and comparative evidence with a sensible account of the changes between PIE and the daughter languages.

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