ABC+Q: Contour segments and tones in (sub)segmental Agreement by Correspondence

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0 INTRODUCTION

- Phonological theory has long been challenged by the behavior of contour segments and contour tones in harmony patterns.

(1) Contour segments: segments with distinct gestures sequenced in time (Sagey 1986; et seq.)
   a. pre- and post-nasalized segments (e.g., *ⁿd, dⁿ*)
   b. affricates (e.g., *ʧ*)
   c. pre- or post-laryngealized segments (e.g., *kʰ, ʰk*)
   d. contour tones (e.g., *ǎ, â, ǎ̀*)
   e. diphthongs (e.g., *aɪ*)
   f. on- and off-glides (e.g., *ʲu, kʷ*)

   (a), (c), see Steriade 1993; 1994; (b), see Lombardi 1990; see also Banner-Inouye 1989 on flaps

(2) Not covered in this talk: complex segments involving distinct gestures which overlap in time
   a. labiovelars, /l/
   b. partially laryngealized vowels
   c. clicks, implosives, ejectives

(3) Conflicting behavior by contour segments in harmony patterns:
- participate in phonology as whole units
- their subsegmental parts act independently

(4) **This talk: ABC+Q**
- Propose new subdivided, *quantized* segmental representations, which allow for a better characterization of the behavior of contour *and* simplex segments.
- Quantized segmental subdivisions are grounded in phonetic reality and tuned to typological phonological generalizations incorporated in Agreement by Correspondence (ABC) theory (Hansson 2001, Rose & Walker 2004).
- ABC+Q marries the representational strength of previous approaches, including Autosegmental Theory, Aperture Theory, and Articulatory Phonology, with the locality and similarity design features of ABC, to capture the unity and internal complexity of segments.
- (Re)unites treatment of segmental phonology and tone.

1 PROPOSED REPRESENTATIONS: QUANTIZED SEGMENTAL SUBDIVISIONS

(5) Segments are subdivided into temporally-ordered, quantized subsegments:

$$Q \rightarrow Q(q^1\ q^2\ q^3)$$

a.	Vowel with triple tone contour	V(à^1 á^2 à^3)	e.g., Mende *mbà̂* ‘companion’
b.	Prenasalized affricate	C(n^1 t^2 ʃ^3)	
c.	Aspirated affricate	C(t^1 ʃ^2 h^3)	e.g., *ʧʰ*

(6) Quantized subsegments *q* are roughly phonetically grounded:

q^1 = Onset, q^2 = Target, q^3 = Release (cf. “landmarks” in Gafos 2002: 271)

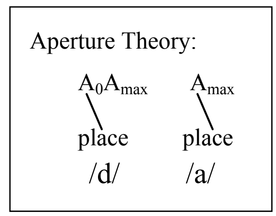
(7) Maximum of 3 *q* subsegments per segment *Q*:

- 2- and 3-tone contours occur; 4-tone contours (e.g., LHLH or HLHL) are typologically rare (e.g., Qiyang: see Hu 2011; or Korean *aegyo* markers; Moon, in prep) and apparently accompanied by lengthening of the host segment (Zhang 2001, et seq.)
- 2- and 3-q segments occur, but not 4-q segments. (Possible exception: Mazatec [^{n}tʃ^{h}]: Pike & Pike 1947; Steriade 1994; but cf. Golston & Kehrein 1998 for an alternative analysis.)

(8) Points of contact with Autosegmental Theory (Leben 1973; Goldsmith 1976), Aperture Theory (Steriade 1993, 1994), and Articulatory Phonology (Browman and Goldstein 1989, et seq.; Gafos 2002; a.o.)

- Similar to Autosegmental Theory and Aperture Theory in positing explicit features for subsegments.
- Similar to Aperture Theory and Articulatory Phonology in positing phonetically-grounded temporal subdivisions with different featural makeup for (some) segments.

(9) Some differences:



- Notion of 'segment' explicit in Q theory (vs. interpretive in Aperture Theory).
- All segments have subdivisions in Q theory.
- Subsegmental architecture is explicitly temporally-ordered.
- Maximum number of subdivisions is 3 in Q theory (vs. 2 in Aperture Theory).
- ➢ All subsegments in Q theory are featurally uniform (contemporaneous): no more multiple associations (cf. Autosegmental Theory).
- ➢ Q theory covers vowels as well as consonants—and tone as well as 'segmental' features.

2 BEHAVIOR OF CONTOUR SEGMENTS AND TONES IN HARMONY PATTERNS

(10) A (working) typology of contours in harmony:

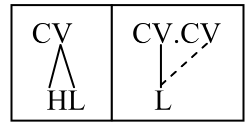
	Whole contour: Q	**Partial contour: q**
Participant	Ngbaka nasal co-occurrence Changzhi, Blang contour tone copying Lalana Chinantec tonal harmony	Samala, Navajo sibilant harmony Guaraní nasal harmony Hakha-Lai partial contour tone agreement Pingyao partial contour tone agreement and whole contour dissimilation Yoruba, Nupe, C. Mazatec contour tone creation
Blocking	Kinyarwanda sibilant harmony	Terena nasal harmony (spread)
Transparent	Kiyaka nasal harmony (similarly, Kikongo)	Oroch [RTR] harmony Runyambo vowel height harmony
Disharmony	Gurindji NC dissimilation Ganda/Meinhof's Law Tianjin, Pingyao, Wuming Zhuang contour tone dissimilation	Basque stop dissimilation

<u>*Conclusion: schizoid behavior:*</u>
- Contours act as units
- Contours don't act as units: their constituent subsegmental *q*'s interact with one another

3 THEORETICAL APPROACHES TO CONTOURS IN HARMONY

(11) Autosegmental representations: driven by individual features or feature bundles

- A feature or class node spreads to adjacent timing slots.
- Correctly predicts assimilation to create or be triggered by parts of contours; has trouble with whole contour behavior (e.g., (15)). Contours are not units in standard autosegmental theory.



(12) Agreement by Correspondence (ABC): existing formulations based on segments

- Corresponding local segment pairs of segments, under conditions of similarity and proximity, are required to be identical in some respect.
  - consonant harmony (Walker 2000; Hansson 2001; Rose and Walker 2004; a.o.)
  - vowel harmony (Sasa 2009; Walker 2009; Rhodes 2010/2012; a.o.)
  - dissimilation (cf. Bennett 2013 (ABC but no similarity scales))
  - tone (esp. consonant tone interactions: Shih 2013)
- Correctly predicts whole segment agreement, including contours, but has trouble with partial contour behavior. The parts of contours are not units in standard ABC.

?	C V_x. C V_x [L] [L]

(13) Needed: Theoretical framework where contours are accessible to operations in part *and* whole
Proposal: ABC+Q (=ABC with enhanced representations)

4 QUANTIZED SEGMENTS: WHOLE AND PARTIAL CORRESPONDENCE

4.1 PARTICIPANT QS IN HARMONY

- ABC deals naturally with whole segments/contours participating in harmony.
- Correspondence and agreement targets segments, Q.

(14) Q_x(q q q)…. Q_x(q q q) .... Pair of corresponding segments

CORR-Q(q q q)--Q(q q q) .... *ABC constraint, establishes correspondence between whole segments meeting a certain threshold of similarity. Correspondence enforced locally on <u>closest eligible pairs</u>*

Ident-QQ-[F] .... *ABC constraint, enforces identity (in [F]) among corresponding segments.*

(15) Changzhi: tone contours copy as unit (see Yip 1989; Bao 1990; data cited from Duanmu 1994)

a.	/kuə$_{213}$ -tə$^{ʔ}_{535}$/	→	[kuə$_{213}$ -tə$^{ʔ}_{213}$]	'pan-DIM'
b.	/səŋ$_{24}$ -tə$^{ʔ}_{535}$/	→	[səŋ$_{24}$ -tə$^{ʔ}_{24}$]	'rope-DIM'
c.	/ti$_{535}$ -tə$^{ʔ}_{535}$/	→	[ti$_{535}$ -tə$^{ʔ}_{535}$]	'bottom-DIM'
d.	/kʰu$_{44}$ -tə$^{ʔ}_{535}$/	→	[kʰu$_{44}$ -tə$^{ʔ}_{44}$]	'pants-DIM'
e.	/təu$_{53}$ -tə$^{ʔ}_{535}$/	→	[təu$_{53}$ -tə$^{ʔ}_{53}$]	'bean-DIM'

(16) CORR-V(T T T)--V(T T T) *Entire vowels correspond*
IDENT-VV([tone] [tone] [tone]) *Corresponding vowels are tonally identical*
IDENT-IO-V([tone] [tone] [tone]) *Vowels are tonally identical in input, output*

(17) **/kuə$_{213}$ -tə$^{ʔ}_{535}$/ → [kuə$_{213}$ -tə$^{ʔ}_{213}$]**

	/kuə$_{213}$ -tə$^{ʔ}_{535}$/	IDENT-VV-V([tone] [tone] [tone])	CORR-V(T T T)--V(T T T)	IDENT-IO-V([tone] [tone] [tone])
Correspondence, identity not enforced	a. / V$_x$(2 1 3)…V$_x$(5 3 5) /	W1		L
Correspondence, identity enforced	☞ b. / V$_x$(2 1 3)…V$_x$(2 1 3) /			1
No correspondence, identity not enforced	c. / V$_x$(2 1 3)…V$_y$(5 3 5) /		W1	L

- Duanmu (1994) uses Changzhi to illustrate a distinction between copying versus harmony/spreading. In ABC, note that there is no formal distinction between these processes.
- Analogous to Ngbaka nasal co-occurrence restrictions (Hansson 2001; Rose and Walker 2004).

4.2 TRANSPARENT QS IN HARMONY

- Quantized subsegments solve a thorny problem in ABC (cf. Walker 2000; Rose & Walker 2004).
- Transparency occurs when a Q does not meet the threshold for correspondence.
- ABC+Q can model threshold for correspondence of segments (Q) based on similarity of subsegmental architecture.

(18) Kiyaka: ^{N}C contours transparent to nasal harmony (Hyman 1995)

a.	kéb-ede	'faire attention'	
	sód-ede	'déboiser'	
b.	kém-ene	'gémir'	*nasal harmony to [+voice] Cs*
	són-ene	'colorer'	
c.	fínúk-ini	'bouder'	*transparency of [-voice] Cs*
	míítuk-ini	'bouder'	
d.	béé^{n}g-ede	'mûrir'	*^{N}Cs don't trigger nasal harmony*
	kóó^{m}b-ede	'balayer'	
	kúú^{n}d-idi	'enterrer'	
e.	méé^{n}g-ene	'haïr'	*transparency of ^{N}Cs*
	náá^{n}g-ini	'durer'	

(19) Hierarchy of correspondence constraints operating on set of voiced consonants:

Most similar	identity	CORR-C(N N N)--C(N N N) CORR-C(D D D)-- C(D D D) CORR-C(N D D)--C(N D D)
Less similar	both simplex but differ in [nas]	CORR-C(N N N)--C(D D D)
Least similar	differ in [nas] *and* simplex vs. contour	CORR-C(N D D)--C(D D D) CORR-C(N D D)--C(N N N)

(20) Ranking of FAITH-IO C([nas]) within the CORR hierarchy prevents agreement between simplex and complex segments:

IDENT-CC-C([nas] [nas] [nas])	*Corresponding C's must be identical, in every q, for [nas].*
»	
CORR-C(N N N)--C(N N N)	*Similar C's must correspond….*
CORR-C(D D D)-- C(D D D)	
CORR-C(N D D)--C(N D D)	
CORR-C(N N N)--C(D D D)	
»	
FAITH-IO-C([nas] [nas] [nas]) ←	*Input and output are identical for [nas].*
»	
CORR-C(N D D)--C(D D D) ←	Ranking prevents correspondence and agreement between simplex and complex Qs = *transparency*
CORR-C(N D D)--C(N N N)	

5 q (SUBDIVISION) CORRESPONDENCE

(21) $q_x \ldots q_x$ .... *Pair of corresponding subsegments*

CORR-q[F]--q[F] .... *ABC constraint, establishes* correspondence *between local pairs of q's meeting a certain similarity threshold [F]*

Ident-qq-[F] .... *ABC constraint, enforces identity (in [F]) among corresponding segments.*

(22) Types of harmony via correspondence, as applied to subsegments *q*:

1. Proximity: adjacent *q*'s correspond.
   (e.g., Yoruba, Ch. Mazatec, Hakha Lai tone; Guaraní nasal harmony)
2. Featural Similarity: *q*'s with similar feature specifications correspond.
   (e.g., Samala sibilant harmony)
3. Structural Similarity: 'prominent' subsegments—i.e., head or target *q*'s—correspond.
   (e.g., Runyambo, Oroch vowel harmonies)

5.1 PROXIMITY: ADJACENT q CORRESPONDENCE

(23) Hakha-Lai partial contour tone agreement (Hyman and VanBik 2002). Adjacent halves of contours must agree across syllable boundaries (as realized after the proclitic *ka*- 'my').

a.	LH-HL		/thlaǎn-zuû/	→	[thlaǎn zuû]	'grave beer'
	HL-LH		/tlaâŋ-tsaǎn/	→	[tlaâŋ tsaǎn]	'mountain time'
	L-LH		/koom-tsaǎn/	→	[koom tsaǎn]	'corn time'
	HL-L		/tlaâŋ-saa/	→	[tlaâŋ saa]	'mountain animal'
	L-L		/koom-saa/	→	[koom saa]	'corn animal'
b.	HL-HL	→ HL-L	/tlaâŋ-zuû/	→	[tlaâŋ zuu]	'mountain beer'
	L-HL	→ L-L	/koom-zuû/	→	[koom zuu]	'corn beer'
	LH-LH	→ LH-HL	/thlaǎn-tsaǎn/	→	[thlaǎn tsaân]	'grave time'
	LH-L	→ L-L	/thlaǎn-saa/	→	[thlaan saa]	'grave animal'

(24) Yoruba: partial assimilation creates contour tone (Akinlabi and Liberman 2000). [For a similar tone pattern, see Chiquihuitlán Mazatec (Jamieson 1977; Yip 2002); for an analogous segmental example, see Terena nasal spread (Piggott 1997, 2003)]

a.	H L	→ H HL	/rárà/	→	[rárâ]	'elegy'
b.	L H	→ L LH	/àlá/	→	[àlǐ]	'dream'

(25) CORR-q[V]-\$-q[V] .... *Vocalic q's across a syllable boundary must correspond*
IDENT-qq-[tone] .... *Corresponding q's should be tonally identical*

(26) **/rárà/ → [rárâ]**

/ V(H H H) … V(L L L) /	IDENT-qq-[tone]	CORR-q[V]-\$-q[V]	IDENT-IO-q[tone]	
a. V(H H H_x) … V(L_x L L)	W1		L	*Correspondence, no identity*
☞ b. V(H H H_x) … V(H_x L L)			1	*Correspondence, identity*
c. V(H H H) … V(L L L)		W1	L	*No correspondence*
d. V(H_x H_{xy} H_{yz}) … V(H_{za} H_{ab} H_b)			W3	*Unnecessary correspondence*

5.2 FEATURAL SIMILARITY q CORRESPONDENCE

(27) Samala (Ineseño Chumash): long-distance, anticipatory coronal harmony between sibilant *q*'s affects *q* subsegments in simplex and contour segments (Applegate 1972; Hansson 2001: 58–59).

Stops and sibilants in Samala: /s, sˀ, sʰ, ʃ, ʃˀ, ʃʰ, t, tˀ, tʰ, t͡s, t͡sˀ, t͡sʰ, ʧ, ʧˀ, ʧʰ/

a.	/k-su-ʃojin/	→	[kʃuʃojin]	'I darken it'
	/s-iʃ-tiʃi-jep-us/	→	[sistisijepus]	'they (2) show him'
b.	/s-api-tʃʰo-it/	→	[ʃapitʃʰolit]	'I have a stroke of good luck'

(28) CORR-q[S]--q[S] .... *Sibilant q's correspond ["S" = sibilant]*
IDENT-qq-[ant] .... *Corresponding q's agree in anteriority*

(29) **/s-api-tʃʰo-it/ → [ʃapitʃʰolit]**

/C(s s s) … C(t ʃ h)/	IDENT-qq-[ant]	CORR-q[S]--q[S]	IDENT-IO-q[ant]
a. C(s_x s_{xy} s_{yz}) … C(t $ʃ_z$ h)	W1 ($s_z$$ʃ_z$)		L
b. C(s_x s_{xy} $ʃ_{yz}$) … C(t $ʃ_z$ h)	W1 ($s_y$$ʃ_y$)		L1
☞ c. C($ʃ_x$ $ʃ_{xy}$ $ʃ_{yz}$) … C(t $ʃ_z$ h)			3
d. C(s_x s_{xy} s_y) … C(t ʃ h)		W1 (sʃ)	L
e. C(s_x s_{xy} s_{yz}) … C(t_{za} $ʃ_a$ h)	W1 ($t_a$$ʃ_a$)	W1 (sʃ)	L
f. C($ʃ_x$ $ʃ_{xy}$ $ʃ_{yz}$) … C($ʃ_{za}$ $ʃ_a$ h)			W4

6 ADVANTAGES OF AN ABC+Q APPROACH

- Two major advantages of a ABC+Q approach to harmony (and disharmony) (contra a feature-spreading approach):

  1. Similarity basis for explicitly stating participant segments.
  2. Ability to capture both long distance and local (CV) phenomena.

6.1 THE SIMILARITY BASIS: CV AND TONE INTERACTIONS

- Similarity basis for harmony patterns afforded by ABC allows direct reference to participating segments in harmony: especially useful for CV and tone interactions (Shih 2013).

(30) Nupe partial spread after L tones to create rising contour is licensed when the intervening onset is [+voice] or sonorant (George 1970; Yip 2002: 143–144).

a.	ètú	'parasite'
b.	èdǔ	'taxes'
	/è-lé/ → [èlě]	'past'
	/è-mí/ → [èmǐ]	'I' or 'me' (in the Kpada dialect; in other dialects = [mĩ])

(31) Nupe pattern can be modeled as (a) correspondence between sufficiently sonorous *q* subsegments across a segment boundary ("S"), using stringent sonority constraints from Shih (2013); and (b) agreement in tone specification:

CORR-q{V,R,N,D}-S-q{V,R,N,D}, IDENT-qq(tone) »
FAITH-IO q(tone) »
CORR-q{V,R,N,K}-S-q{V,R,N,K}

Optimal candidate [èdǔ]
(e_x e_x e_x) (d_x d_x d_x) (u_x u_y u_y) [L][L][L] [L][L][L] [L][H][H]

7 EXTENSIONS AND PREDICTIONS

- Disharmony
- Q/q independence
- Opacity – simplex segments can be opaque to interactions between contours and vice versa
- String-to-string correspondence

7.1 DISHARMONY AND Q/Q INDEPENDENCE

- ABC+Q analysis can extend to disharmony: corresponding segments undergo anti-agreement (cf. Bennett 2013).
- Q's and q's can behave independently with respect to agreement and disagreement.

(32) Tianjin whole contour *Q* dissimilation and partial contour *q* dissimilation (Chen 1985; Yip 1989: 163; 2002: 51, 179)

Adjacent whole tones dissimilate: contours simplify; adjacent L's will have H insertion.
Adjacent subsegments (*q*'s) across a syllable boundary must also disagree in tone.

a.	LH.LH	→ H.LH	*HL.LH	/xi_{LH}/	→	[xi_H.$lian_{LH}$]	'wash one's face'
	HL.HL	→ L.HL	*LH.HL	/$jing_{HL}$/	→	[$jing_L$.$zhong_{HL}$]	'net weight'
b.	L.L	→ LH.L		/fei_L/	→	[fei_{LH}.ji_L]	'airplane'
c.	HL.L	→ H.L					

¬IDENT-QQ-[tone] and ¬IDENT-qq-[tone] both active.

(33) Pingyao whole contour *Q* dissimilation and partial contour *q* agreement (Chen 1992; data from Yip 2002: 196)

Unlike Tianjn, Pingyao demonstrates disagreement at the syllable/segment level and agreement at the subsegmental level (across syllable boundaries) (see also Hakha Lai for a similar pattern).

a.	hai$_{35}$ bing$_{35}$	→	[hai$_{53}$ bing$_{35}$]	'become ill'
b.	er$_{53}$ ruan$_{53}$	→	[er$_{35}$ ruan$_{53}$]	'ear soft, i.e. gullible'

¬IDENT-QQ-[tone] and IDENT-qq-[tone] both active.

7.2 OPACITY AND STRING-TO-STRING CORRESPONDENCE

- ABC+Q allows reference to simplex and contour segments simultaneously: no longer is ABC restricted to purely segmental correspondence.

(34) Gurindji: correspondence induces opacity of simplex segments to contour dissimilation (see also similar patterns in other Australian languages (survey from Bennett 2013: 583): e.g., Bardi (Bowern 2004); Gooniyandi (McGregor 1990; Evans 1995; Suzuki 1998); Nhanda (Blevins 2001); Yindjibarndi (Wordick 1982; Suzuki 1998)) (cf. contour opacity to simplex segments in Kinyarwanda (Walker and Mpiranya 2006))

^{N}O…^{N}O dissimilation (via Spence 2010) ("O" = oral stop; [j] = laminal palatal stop)

a. ^{N}O…^{N}O dissimilation to ^{N}O…O
wi**ɲj**i-**ŋk**a → wi**ɲj**i**k**a 'spring-LOC'
ka**ɲj**u-**mp**al → ka**ɲj**u**p**al 'down-across'
ŋari**n-k**u**ɲj**a → ŋari**nk**u**j**a 'meat-LACK'

b. ^{N}O…^{N}O dissimilation blocked by intervening O or N
pa**ɳk**u-**ʈ**i-**ŋk**uɾa → paɳkuʈiŋkuɾa 'cross_cousin-KIN-ALL'
kuya-**ŋk**a-**m**a-**ŋk**u pa-ni → kuyaŋkama**ŋ**ku pani 'thus-LOC-TOP-2SG.OBJ hit-PST'

c. Nonnasal sonorants transparent to ^{N}O…^{N}O dissimilation
ŋu-**ɲj**uɾa-**ŋk**ulu → ŋu**ɲj**uɾa**k**ulu 'AUX-2PL.OBJ-3PL.SUBJ'
pa**ɳk**u-ku**ɲj**a → pa**ɳk**uwu**j**a 'cross_cousin-COMIT'

(35) CORR-C(N C C)--C(C C C) *A pair of C's, in at least one of which q^{1}=N, must correspond*
¬IDENT-CC-C(N O O) *Corresponding C's cannot both be nasal-oral contours*

(36) /wi**ɲj**i-**ŋk**a/ → [wi**ɲj**i**k**a]

/ C(ɲ j j) … C(ŋ k k) /	¬IDENT-CC-C(N O O)	CORR-C(N C C)--C(C C C)	IDENT-IO
a. C_x(ɲ j j) … C_x(ŋ k k)	W1		L
☞ b. C_x(ɲ j j) … C_x(k k k)			1
c. C(ɲ j j) … C(ŋ k k)		W1	L

(37) /kuya-**ŋk**a-**m**a-**ŋk**u/ → [kuya-**ŋk**a-**m**a-**ŋk**u]

/ C(ŋ k k) … C(m m m) … C(ŋ k k)/	¬IDENT-CC-(N O O)	CORR-C(N C C)--C(C C C)	IDENT-IO
☞ a. C_x(ŋ k k) … C_{xy}(m m m) … C_y(ŋ k k)			
b. C_x(ŋ k k) … C_{xy}(m m m) … C_y(k k k)			W1
c. C_x(ŋ k k) … C(m m m) … C_x(ŋ k k)	W1	W2	
d. C_x(ŋ k k) … C(m m m) … C_x(k k k)		W2	W1

Here, opacity is introduced by a mismatch between what must correspond {O, N, ^{N}O} and which corresponding pairs are affected by anti-Identity = {^{N}O}only.

(38) With the ability to reference simplex and contour segments at once, ABC+Q begins to converge with string-to-string correspondence in Aggressive Reduplication (Zuraw 2002) or what Yu (2007) calls 'compensatory reduplication' and Inkelas (2008) calls 'phonological reduplication'.

- Similarity in the internal composition of a segment or of a string play into correspondence and harmony patterns.
- Formally, see also MAX-ABC (McCarthy 2010), which uses Aggressive Reduplication-reminiscent constraints in an ABC system. (Subtle differences in predictions still need to be worked out (see Zuraw 2002: 434–435; Shih, in prep).)

8 CONCLUSION

ABC: *Why use ABC for harmony, rather than (say) autosegmental spreading?*

- similarity among participating segments is a design feature, not a stipulation
- autosegmental spreading is phonologization of coarticulation (=temporal extension of gesture/percept); ABC models both coarticulation and motor planning effects

Q: *Why modify the representations referred to in ABC?*

- Quantized segments endow ABC with the ability to deal with phenomena beyond (and inside) segmental correspondence.
- Q-theory unites segments and tone under one treatment of harmony/disharmony.
- Q-theory further parameterizes locality (syllable-level, mora-level, segment-level, **subsegment-level**).

- ABC+Q can capture three types of harmony where participant segments are stated over the following:
  1. proximity
  2. featural similarity
  3. structural similarity

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