

Cross-level Correspondence in Q Theory

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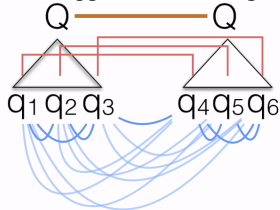
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1 Introduction

This paper examines cross-level interactions in basic systems modeling segmental harmony in Q theory (Shih & Inkelas 2019, S&I; see also Inkelas & Shih 2015, 2017). Q theory is a theory of segmental representations that decomposes segments (Q s) into linear strings of subsegments (q s). The component q s can differ in feature values, resulting in Q s with contour tones.¹ For example, the q sequence [á à á] represents the Q á. S&I present Q theory as an alternative to autosegmental representations and use Agreement-by-correspondence (ABC; Rose & Walker 2004, Hansson 2010, Bennett 2015) analyses to derive various kinds of harmony and dissimilation patterns, particularly those involving tones.

In ABC, interactions between segments—including long distance ones—arise due to a surface correspondence relationship over segments in the output, enforced by CORR constraints. Separate CCID constraints are violated by non-identity between correspondents, analogous to input-output (IO) correspondence constraints. Harmony occurs when correspondents are unfaithfully mapped to match feature values (dissimilation can occur for related reasons; see Bennett 2015). In non-Q theory, these constraints refer to features of segments; Q theory makes the subsegmental level available as well, allowing for constraints to reference either levels. They can then enforce correspondence and identity relations for either q s or Q s, causing assimilation of individual features (harmony at the q level), or contours of features (harmony at the Q level). The possible relations are illustrated in (1). Red indicates Q -level correspondence (calculating as string-to-string correspondence between the Q s connected by the top orange line); blue indicates the potential q -level correspondences.

(1) Q and q possible correspondence relations



Widening the set of possible candidates and constraints gives rise to the question of what typological consequences this double-reference has. While work in Q theory has examined particular case studies in detail, the full effect of having constraints at both levels, and how one can influence the other, have not been examined.

This paper analyzes basic typologies of agreement in Q theory to show how correspondence or its lack at structural one level affects that at the other. The typologies are analyzed in Property Theory (PT; Alber, DelBusso & Prince 2016, Alber & Prince in prep., DelBusso 2018), which decomposes a typology into a set of properties that represent the key ranking choices and explains their connection to empirical traits in the predicted languages. This paper shows that while the Q theory typologies share the characteristic structures of ABC(D) systems (Bennett & DelBusso 2018, DelBusso & Bennett to appear) at both q and Q levels, these (sets of) properties interact in more complex embedded structures. The first system, QqCor, shows the consequences of q -harmony for Q -harmony and vice versa: while q -harmony entails Q -harmony, the lack of the reverse entailment results in the interdependence of three choices regarding harmony vs. faithfulness. The second system, QqEdge, adds a CC-limiter constraint. In this typology, the structure of

* Thanks to Sharon Inkelas, Stephanie Shih and attendants at AMP 2019 for insightful discussion and questions.

¹ S&I also use such q s for complex segments like diphthongs, affricates, or prenasalized consonants.

QqCor is maintained, but another kind of language also occurs, in which *q*-harmony can occur in the absence of *q*-correspondence. The results of the analyses show that the kind of dual-level reference made available by *Q* theory allows for languages with mixes of harmony and non-harmony in optima.

2 Qq Systems

Two *Q* theory systems are analyzed: QqCor, and an extension thereof, QqEdge. In both, inputs and outputs consist of two *Q* segments, each of which is made up of a string of two *q*'s.² Following S&I, the analysis models tone interactions, and each *q* is defined by a tone feature value. A *Q* has a level tone when both *qs* are the same value, and a rising/falling tone when the *qs* are different (2).

(2) Qs and qs

Level low	Level high	Rising	Falling
Q /\	Q /\	Q /\	Q /\
l l	h h	l h	h l

GEN (3) produces forms consisting of two *Q*s, each comprising two *qs*. Each *q* is defined by a feature value for tone: high (h) or low (l), e.g. [hh] or [hl].

(3) GEN³

- a. Inputs: [qq]Q[qq]Q, $q \in \{h,l\}$.
- b. Outputs: [q#qy#]X[q#q#]Y,
 where: $q \in \{h,l\}$,
 $\# = q$ correspondence indices {1,2,3,4},
 $X, Y = Q$ correspondence indices {x,y}.

CON contains three central ABC constraint types for each of the two levels: 1) CORR, violated by non-correspondence between *Q*s or *qs*; 2) CC.ID, violated for lack of feature identity between correspondent *qs* or *Q*s; 3) IO faithfulness. Correspondence for each level is independent of that for the other: two *Q*s may be in correspondence even if none of their component *qs* are (and vice versa), indicated by distinct notations for correspondence indices. Identity is also assessed differently. For *q*, it is assessed for every corresponding pair (using Bennett's 2015 definition of correspondence), regardless of whether they are in the same or different *Q*s, and is based on the feature identity of the pair. For *Q*s, it is based on string-to-string equivalence (S&I, Zuraw 2002): two *Q*s are identical if their sequences of *qs* are. For example, [hl]_A = [hl]_B, but [hl]_A ≠ [lh]_C; while A and C both contain a h and l, they are in different orders.

IO faithfulness is similarly distinct at the two levels. The f.Q constraint assigns a violation if there is any difference in any of the *qs* of the input-output *Q* correspondents (categorical, assigning at most 1 violation per *Q*). A single *Q* may have multiple violations of f.q if both *qs* are changed. The second system, QqEdge, adds a CC.Limiter constraint, CCq.QED, violated by correspondence between *qs* in different *Q*s, similar to how other CC.Limiter constraints are violated by correspondence across other kinds of morphological and phonological boundaries (Bennett 2015). Constraints are defined in (4).

(4) CON

Constraint	Definition (capitals = <i>Q</i> s, lowercase = <i>qs</i>)
CORR.Q	*(A _x , B _y) <i>non-corresponding Qs penalized; satisfied by Q:Q correspondence</i>
CORR.q	*(a ₁ , b ₂) <i>non-corresponding qs penalized; satisfied by q:q correspondence</i>

² S&I hypothesize a 'maximally tripartite' *Q* (S&I, §3), which allows for *Q*s consisting of fewer than 3 *qs*. The systems here use 2 *qs*, which keeps GEN to a manageable size while still showing the main interactions that occur with multiple structural levels.

³ The systems here use a transitive correspondence relation (following Bennett 2015); S&I use non-transitive. Matching numbers indicate correspondence.

CCID.Q	* $(A_x, B_x): (a_i \in A) \neq (b_i \in B)$ <i>lack of string-to-string identity of q's in Qs penalized; satisfied by string harmony</i>
CCID.q	* $(a_1, b_1): a \neq b$ <i>non-identical corresponding qs penalized; satisfied by segmental harmony</i>
CCq.QED	* $(a_1, b_1): (a \in A), (b \in B), A \neq B$ <i>corresponding qs in different Qs penalized; satisfied by non-cross-Q correspondence</i>
f.Q	* $(I, O): I \neq O$ <i>non-identical input-output Qs penalized; satisfied by faithful mappings</i>
f.q	* $(i, o): i \neq o$ <i>non-identical input-output qs penalized; satisfied by faithful mappings</i>

To illustrate the differences between the violation profiles of the Q - and q -specific constraints, the optimal candidate set (cset) for input [hl][hh] is shown in (5). There are five possible optima (non-harmonically bounded candidates) for the QqCor system. As the tableau shows, violation of CORR.Q does not entail violation of CORR.q or vice versa. It is possible for one representational level to be in correspondence while the other is not, and similarly for harmony (violations of CC.ID constraints). For this input, the violation profiles of the faithfulness constraints are equivalent for all possible candidates, as the harmony candidate has a single unfaithfully-mapped q (in one Q). This is not the case for all inputs, as discussed more below.

(5) Optima and violations for [hl][hh]

Input	Output	Corr.Q	Corr.q	CC.IDQ	CC.IDq	f.Q	f.q	Mapping type
[hl][hh]	[h1h1]x[h1h1]x					1	1	Q & q har
	[h1l1]x[h1h1]x			1	3			Q & q cor
	[h1l2]x[h1h1]x		3	1				Q cor / q cor for h, noc for l
	[h1l1]x[h1h1]y	1			3			Q noc / q cor
	[h1l2]x[h1h1]y	1	3					Q & q noc

When CCq.QED is added in QqEdge, the set of possible optima expands to ten candidates outlined in bold in (6). This constraint acts as a general anti-correspondence constraint between subsegment q s in different Q s. In the added possible optima, q s in separate Q s do not correspond, adding violations of CC.IDq, but satisfying CCq.QED.

(6) Optima and violations for [hl][hh] in QqEdge

Input	Output	Corr.Q	Corr.q	CC.IDQ	CC.IDq	f.Q	f.q	CCq.QED	Mapping type
[hl][hh]	[h1h1]x[h1h1]x					1	1	4	Q & q har
	[h1l1]x[h1h1]x			1	3			4	Q & q cor
	[h1l2]x[h1h1]x		3	1				2	Q cor / q cor for h, noc for l
	[h1l1]x[h1h1]y	1			3			4	Q noc / q cor
	[h1l2]x[h1h1]y	1	3					2	Q & q noc
	[h1h1]x[h2h2]x		4			1	1		Q & q har / q cor within-Q only
	[h1l1]x[h2h2]x		4	1	1				Q cor / q cor within-Q only
	[h2l3]x[h1h1]x		5	1					Q cor / q noc in Q1, cor in Q2
	[h1l1]x[h2h2]y	1	4		1				Q noc / q cor within-Q only
	[h2l3]x[h1h1]y	1	5						Q noc / q noc in Q1, cor in Q2

3 Typologies and Analysis

The full typologies for both systems were calculated in OTWorkplace (Prince, Merchant & Tesar 2007-2019) and analyzed with Property Theory (PT; & Prince in prep., Alber, DelBusso & Prince 2016, DelBusso 2018). A Property Analysis (PA) identifies the central rankings and constraint interactions that define the grammars of the typologies and, in turn, their alignment with particular extensional traits of optima. In defining a set of properties and their dependencies, a PA shows the specific constraint interactions that give rise to the predicted languages. Each grammar in the typology is defined by a unique set of property values (α or β).⁴

3.1 *QqCor* There are 9 grammars in the *QqCor* typology, with languages differing in whether they have tone harmony (har), correspondence (cor), or non-correspondence (noc), at both and/or either the *Q* and *q* levels.⁵ The table in (7) shows optima for three representative inputs that distinguish the languages. For each input, there is a three-way choice of mapping available for both *Q* and *q*.

The choices at the different levels are not entirely independent. *Q*-har is entailed by *q*-har: if *qs* are all identical, then *Qs* containing them are identical too, and consequently incur no violations of the *Q*-level ABC constraints when in correspondence. The reverse does not hold: the string-to-string correspondence between *Qs* allows for satisfaction of CC.IDQ *without* all *qs* being the same (e.g. in contour harmony, [hl]_x[hl]_x, where the *qs* comprising each *Q* are different, but the *Qs* are identical to one another). Because of this non-entailment, a second *q*-har choice arises for those languages where harmony between *Qs* obtains, but harmony between *qs* is not strictly required. This separates L2 and L4 from L3 and L5. These languages are ‘mixed’, in that they enforce *q*-level harmony in the outputs for some inputs, but not for others. For instance, in L2: the input /[hl][lh]/ undergoes harmony to become [hh][hh] (or its co-optimal alternative, [ll][ll]⁶), but the input /[hl][hl]/ is realized faithfully (with correspondence between the non-identical *qs*). This kind of mixed harmony pattern is unusual in analyses of harmony, and such languages are only produced in systems where constraints refer to different levels.

(7) *QqCor* factorial typology⁷

	[hh][hl]		[hl][hl]		[hl][lh]	
	Q	q	Q	q	Q	q
L1	har	har	har	har	har	har
L2	har	har	har	cor	har	har
L3	har	har	har	cor	har	cor
L4	har	har	har	noc	har	har
L5	har	har	har	noc	har	noc
L6	cor	cor	har	cor	cor	cor
L7	cor	noc	har	noc	cor	noc
L8	noc	cor	har	cor	noc	cor
L9	noc	noc	har	noc	noc	noc

The internal structure of the typology is organized around the same core ranking choices and correlated traits characteristic of ABC(D) systems generally, with sets of interacting constraints of the three types: CORR, CCID, and f (Bennett & DelBusso 2018, DelBusso & Bennett to appear). However, in *QqCor*, these occur at both the *Q* and *q* levels, and are interdependent, as brought out in the structure of the Property Analysis (PA). There are five properties in three sets, {P1q, P2q}, {P1Q, P2Q} and {P3q}, that determine the parallel ranking choices over the different levels of representation, aligning with parallel extensional

⁴ For more discussion of PT and PAs, see the cited sources; for analyzes of ABC(D) and related systems in PT, see Bennett & DelBusso 2018, DelBusso & Bennett to appear.

⁵ No dissimilation mappings are optimal; see Bennett & DelBusso 2018 on necessary conditions for these.

⁶ No constraint(s) in this system control the direction of harmony when multiple options incur the same number of faithfulness violations, resulting in co-optima for outputs.

⁷ A language is described as ‘cor’ only if all (sub)segments are in correspondence in the absence of (full) harmony.

traits (8a).⁸ The scope relationships between them explain the generalizations discussed above regarding how (non-)harmony at one level affects that at the other.

P1_q—which aligns with the choice of whether *Q*s harmonize with each other—scopes under P1_q.β, the value correlated with lack of *q*-har ($\{f.Q, f.q\}.dom \gg \{CORR.q, CCID.q\}.sub$). In languages that have *q*-har (P1_q.α: $\{CORR.q, CCID.q\}.sub \gg \{f.Q, f.q\}.dom$), harmony at the *Q*-level is entailed: changing the *q*s to match one another yields *Q*s that also match. The *Q*-level correspondence constraints are therefore satisfied and are not crucially ranked relative to the faithfulness constraints (the ranking determined by the PQ properties). The properties and their associated traits are described in greater detail below.

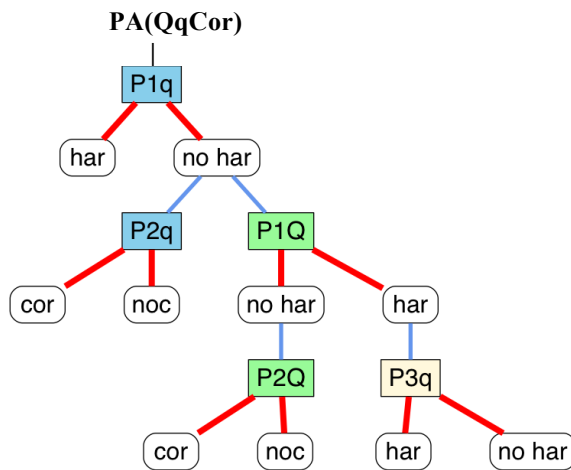
The treeoid (Alber & Prince in prep.) showing the structure of the PA (8b) is annotated with the associated extensional traits. The 9 languages of the typology are defined by the value sets in the value table (8c).

(8) PA(QqCor)

a. Properties

P1 _q	$\{CORR.q, CCID.q\}.sub \triangleleft \{f.Q, f.q\}.dom$ /[hh][hl]/ → α. [hh][hh] / β. [hh][hl]
P2 _q	Corr.q <> CCID.q /[hh][hl]/ → α. [h1h1][h111] / β. [h1h1][h112]
P1 _Q	$\{CORR.Q, CCID.Q\}.sub \triangleleft \{f.Q, f.q\}.dom$ /[hh][hl]/ → α. [hh]x[hh]x / β. [hh]x[hl]x/y
P2 _Q	Corr.Q <> CCID.Q /[hh][hl]/ → α. [hh]x[hl]x / β. [hh]x[hl]y
P3 _q	$\{CORR.q, CCID.q\}.sub \triangleleft f.Q$ /[hl][lh]/ → α. [hh][hh] or [ll][ll] / β. [hl][hl] or [lh][lh]

b. Treeoid



⁸The sub and dom operators pick out the lowest and highest ranked constraint in the set to which it is appended (Alber & Prince in prep.). For example, $\{CORR.q, CCID.q\}.sub$ refers to CCID.q if $CORR.q \gg CCID.q$, and to CORR.q under the reverse ranking.

c. Value table

	P1q	P2q	P1Q	P2Q	P3q
L1	α				
L2	β	α	α		α
L3	β	α	α		β
L4	β	β	α		α
L5	β	β	α		β
L6	β	α	β	α	
L7	β	β	β	α	
L8	β	α	β	β	
L9	β	β	β	β	

P1q and P3q both antagonize the same q -level correspondence constraints against the IO faithfulness constraint(s). P3q is embedded (transitively) under P1q. β : it requires one of the faithfulness constraints to dominate the subordinate member of the q -level ABC constraints {Corr.q, CCId.q}. Under this ranking, the optimum for an input like [hl][hl] is faithful, without q -level harmony, and it violates both f.Q and f.q twice (requiring a change in feature value in two qs — one in each Q). However, the optimum does satisfy both Q -level correspondence constraints, as the Qs are string-to-string identical.

The situation is different for inputs with disagreeing contours like [hl][lh], where neither $q:q$ nor $Q:Q$ identity occurs in faithful candidates. Q -har can be achieved in two ways, differing in the degree of violation of f.Q: (a) change only one Q , by reversing the tone values of its component q (1 violation of f.Q; e.g. contour tone [hl][hl]); or, (b) change both Qs so that all qs are identical (2 violations of f.Q, 1 for each Q ; e.g. level or plateau tone [hh][hh]). Both changes incur the same number of f.q violations, as two qs are changed in either case of harmony. However, only (b) satisfies both of the q -level correspondence constraints. P3q encodes this conflict between Q -level faithfulness and q -level ABC constraints. This choice only arises when other conditions obtain— q -har must not occur generally (P1q. β), and Q -har must (P1Q. α)—and so P3 is scoped under P1Q. α .

The two options (a) and (b) are the only agreement options that are possible optima for the input [hl][lh]. A candidate with an output of [hl][ll], where one contour is maintained in one Q but not the other, is harmonically bounded. This candidate fails to satisfy any of the three constraint types, and is inconsistent with either value of P1q.

The PA thus shows how choices at different structural levels are contingent on choices made at other levels. Having multiple levels of structure allows for languages that have harmony for some inputs but not for other, a choice made not on the basis of different features (as in the systems studied in Bennett & DelBusso 2018, DelBusso & Bennett to appear), but rather on the basis of the segment vs. subsegment distinction. While q -harmony entails Q -harmony, the lack of the reverse entailment results in the embedded structure of the properties and the correlated choices of harmony. The structure of the typology thus recapitulates the structure in the Q -theoretic representation.

3.2 $QqEdge$ The second system, $QqEdge$, adds a constraint to CON that serves to limit q -correspondence between qs in different Qs . The resulting typology replicates the structure of the $QqCor$ typology in two separate halves: one with $q:q$ correspondence, and one without. The properties of $QqCor$ carry over, with one additional property. This system also generates another type of language, where q -har does *not* entail q -cor, though such entailment continues to hold at the Q level.

The factorial typology contains 20 languages. In addition to 9 that match up with those of $QqCor$, there are an additional 11 languages in which $q:q$ correspondence never holds across a Q boundary in optima, even for inputs where all qs are identical (i.e. where correspondence would incur no violation of CC.ID). This division aligns intensionally with choice of value on the new property, P4 ((9), showing the optima for input [hh][hh]). These values track the distinction between have q -cor only within a Q (α) or also across Qs (β).⁹ In the $QqCor$ typology, harmony entails correspondence, and for an input with identical qs , there is a single possible optimum (cor). Adding the $Q:Q$ edge constraint introduces a potential reason for languages to prefer non-correspondence here as well.

⁹ Correspondence indices at the Q level not shown; this is not determined by P4.

- (9) PA(QqEdge): P4
 CCq.QEd \leftrightarrow Corr.q
 α . noc: [hh][hh] \rightarrow [h1h1][h2h2]
 β . cor: [hh][hh] \rightarrow [h1h1][h1h1]

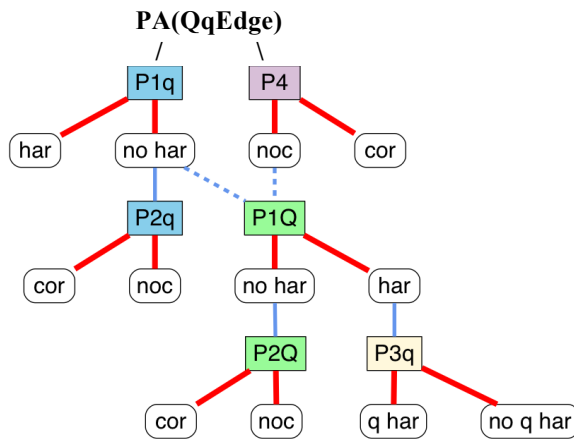
P4 is a wide-scope property: all grammars in the system have a value. Its addition allows for a new type of language: *q*-har with *q*-noc. Both the {P1, P2} set and P4 are linked to extensional traits of *q*-level correspondence, but as they involve distinct CC constraints—CC.IDq in the first case and CCq.QED in the second—their values are freely combinable. The three combinations of {P1, P2} define the three types, har, cor and noc; P4 values split each of these depending whether they occur only within a *Q* (α) or across the *Q* boundary (β) (10).

(10) Value combinations of (non-)correspondence

P1q	P2q	Type	P4	Domain
α		har	α	within-Q
			β	cross-Q
β	α	cor	α	within-Q
			β	cross-Q
β	β	noc	α	within-Q
			β	cross-Q

The addition of P4 results in another change to the PA: the scope of P1Q is expanded from P1q. β to the disjunction of P1q. β or P4. α (disjunctivity shown as dashed lines in the treeoid in (11)). Both values encode rankings in which *q*-level correspondence constraints are dominated: CORR.q under P4. α , and CORR.q or CCID.q under P1q. β . This expansion results in another type of mixed harmony language: one where harmony is bounded by *Q* edges. For inputs like [hl][hl], the optimum is [h1h1]x[h2h2]x (or [111]x[1212]x), which while having *q*-har both in and across *Q*s, lacks *q*-cor. However, when *q*s within each *Q* are identical, as for input [hh][ll], no cross-*Q* harmony occurs, and the optimum is a faithful candidate. Such grammars have P1q. α (*q*-har) and P4. α (*Q*-edge bounding of *q*-correspondence).

(11) Treeoid



QqEdge thus maintains the structure of the QqCor typology. It adds a single property that interacts with the previous properties, allowing for a larger range of (non-)correspondence and agreement mappings.

4 Summary and conclusions

Previous work in *Q* theory focuses mainly on interactions occurring at either the *Q* or *q* level to account for certain kinds of tone patterns. Through analysis of typologies with a full constraint set for both levels, this paper shows interactions that arise across the levels, highlighting the importance of examining typologies in their completeness, rather than isolating specific extensional phenomena.

The paper shows that cross-level interactions are limited in scope and diversity. Under standard assumptions about correspondence, lower-level pressures for harmony combine harmoniously with higher-level harmony, rather than conflicting. In the systems here, no properties antagonize *Q*-level ABC constraints against other *q*-level ABC constraints; cross-level interactions only arise from interactions of ABC and faithfulness constraints (as in P3).

The systems analyzed in this paper share the typological structure characteristic of ABC system more generally (Bennett & DelBusso 2018, DelBusso & Bennett to appear). However, that structure occurs over two levels of representation, and choices of harmony at each are embedded under one another.

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