Re-representing phonology: consequences of Q Theory*

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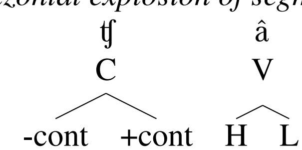
1. Introduction

Since the development of Optimality Theory (OT; Prince & Smolensky (2004)) and Harmonic Grammar (HG; Legendre et al. (1990)) in the 1990's, phonological theory has focused on the grammatical constraints that conspire to produce output generalizations.

In the 1970s and 1980s, however, the focus was on representations, both above and below the level of the segment. Traditional feature matrices gave way to the autonomous features of Autosegmental Phonology (Leben (1973, 1978, 1980); Goldsmith (1976), McCarthy (1981)). The ability of features to link independently to timing units permitted, among other things, the representation of contour segments:

(1) *Horizontal explosion of segments: Autosegmental Phonology*



Feature geometry (Clements (1985), Sagey (1986), McCarthy (1988)) organized autonomous features into sets, represented as constituents of a tree-like structure:

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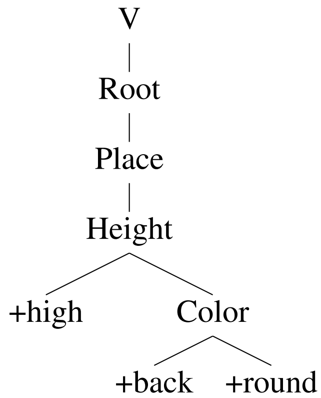
(2) *Vertical explosion of segments: Feature Geometry*



Aperture Theory (Steriade (1993, 1994)) decomposed certain segments into a sequence of ordered subsegments, giving autonomous existence to closure and release phases of stop consonants. Articulatory Phonology (Browman & Goldstein (1986), Gafos (2002), inter alia) combined several of these concepts, treating the gestural subcomponents of segments as autonomous and also permitting the timing of the onset and offset of each gesture to be specified independently within the same segment.

Reversing the trend of looking inside the segment, contemporary phonology in OT and HG has been highly segment-oriented. Theories of harmony and disharmony within these surface-oriented, constraint-based models rely on segmental correspondence, using traditional segments as basic representational units. This representationally conservative view is clearly evident, for example, in Agreement by Correspondence theory (ABC; Hansson (2001), Rose & Walker (2004), Bennett (2013), inter alia) in which the correspondence constraints driving harmony and disharmony refer explicitly to segments as the basic units that interact. To some extent, this is because the grammatical richness of ABC may render obsolete some of the considerations that initially drove the representational explosion of the segment. For example, work on feature classes by Padgett (1995) essentially obviated feature-geometric representations as in (2). However, as will be argued in this paper, many of the issues driving the horizontal representational explosion of the segment remain valid.

Q Theory, outlined in this paper and in Inkelas & Shih (2013), Shih & Inkelas (2014), joins recent proposals to enrich contemporary surface-oriented grammars with greater representational complexity. These proposals include the guttural feature classes of Moisik (2013) and Sylak-Glassman (2014) and the tone complexes of Akinlabi & Liberman (2001). Recent proposals to enrich phonological representations with phonetically motivated structure include the C- and V-gestures of Gick (2003), the articulatory-acoustic mappings of Boersma (2011), the motor-acoustic mappings of Byun et al. (2016), the biomechanical 'modules' of Gick & Stavness (2013) and Derrick et al. (2015), and Lionnet's subfeatures (Lionnet 2014, this conference).

The specific contribution of Q Theory is to explode the segment into a series of up to three temporally ordered subsegments, quantizing and reifying the informal concepts of transition into, target, and transition out of a vowel or consonant. One primary goal is to account for the behavior of contour segments, going beyond currently available representational and surface-optimizing theories.

2. Contour segments

Contour segments are segments with distinct gestures sequenced in time. Sagey (1986) was one of the first to call attention to the need for more nuanced representations of these segments than what the feature matrices of *SPE* (Chomsky & Halle 1968) had to offer. Contour segments include pre- and post-nasalized segments (e.g., ^{n}d, d^{n}) (Sagey 1986, Steriade 1993), affricates (e.g., *ʧ*) (Sagey 1986, Lombardi 1990, Steriade 1994, Kehrein & Golston 2004), pre- or post-laryngealized segments (e.g., ^{h}k, k^{h}) (Sagey 1986, Steriade 1994), contour tones (e.g., *ǎ, â, a᷈*), diphthongs (e.g., *aɪ*), and consonants with on- and off-glides (e.g., p^{j}, k^{w}).

How contour segments participate in harmony and disharmony is a challenge to segment-oriented representations: contour segments act like single units in some processes, but like sequences in others. Q Theory directly addresses this problem.

3. Q Theory: quantizing contours as strings of subsegments

In Q Theory (Inkelas & Shih 2013, Shih & Inkelas 2014), each vowel and consonant is subdivided into three quantized ‘*q*’ subsegments. In the schematic representation in (3), *‘Q’* represents a traditional segment, and varies over *‘V’* (for vowel) and *‘C’* (for consonant). ‘*q*’ varies over ‘*v*’ and ‘*c*’, the subsegments comprising a vowel or consonant, respectively.

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

Nothing vital hinges on the distinction between *V* and *C*, or *v* and *c*. Each subsegment is a uniform feature bundle; its major class feature values etc. determine its interpretation, in context, as a vowel vs. a consonant.

Q Theory is designed to represent all manner of contour (as well as apparently simple) segments. In (4), numerical superscripts are omitted from *q*’s, for legibility:

(4) *Contour segments, represented in Q Theory*

a:	V(a a a)	*k:*	C(k k k)	*â*:	V(á à à)
ai:	V(a a i)	k^{h}*:*	C(k k h)	*ǎ*:	V(à á á)
ia:	V(i a a)	^{n}d*:*	C(n d d)	*a᷈*:	V(à á à)

4. Relation to previous approaches

Q Theory is related to a number of previous approaches to the representation of the segment, synthesizing the key insights of each with one another into a more comprehensive approach. Here we touch on Autosegmental Phonology, Aperture Theory, and Articulatory Phonology.

4.1 Points of contact with previous approaches

Q Theory resembles **Autosegmental Phonology** (Leben 1973, Goldsmith 1976, Sagey 1986, inter alia) in positing feature sequencing within a single segment, as seen in the examples of [continuant] and tone sequencing in the representations of an affricate and a contour tone in (1), above.

Q Theory resembles **Aperture Theory** (Steriade 1993, 1994) in positing that segments have internal temporal structure, with separately represented closure and release phases. In Aperture Theory, each phase is represented by one of three types of aperture nodes. A_0 represents maximum construction, as in a stop. A_f represents a fricative, and A_{max} represents minimal constriction, as in an approximant. Example (5) illustrates the representational distinction between a pre-glottalized and post-glottalized stop (Steriade 1994:207):

(5) *Pre- vs. post-glottalized stop*

ˀt:	constricted		tˀ:		constricted
	│				│
	A_0	A_{max}		A_0	A_{max}

Articulatory Phonology (Browman & Goldstein 1986, Gafos 2002) posits, for each segment, a set of ‘landmarks’ (movement onset, target and release) around which the timing of segment-internal gestures are organized. Gafos uses the term ‘gestural plateau’ to characterize “[t]he portion of the trajectory between target and release” (p. 276); in Q theory, this is q^2. The continuous internal gestural makeup of segments in Articulatory Phonology maps in Q Theory to quantized, discrete stages in a segment.

4.2 Points of departure from previous approaches

Though incorporating key insights from Autosegmental Theory, Aperture Theory and Articulatory Phonology, Q Theory is distinct from each of these in certain important ways.

First, in Q Theory all segments, including vowels, have subdivisions, thus bringing tone contours, diphthongs, and more under the scope of the theory. In Aperture theory, only released stop consonants are complex.

Second, in Q Theory, there is a maximum of three subsegments per segment, whereas Aperture Theory provides only two (and only for released stops; unreleased stops and approximants have only one (Steriade 1994:210)). For contour consonants, Aperture Theory lacks a dedicated representation for the ‘target’ phase, which theories such as Articulatory Phonology have shown to be important in the internal organization of phones. In Q Theory, subsegmental divisions are discrete and not associated with specific phonetic durations; by contrast, the timeline of the gestural score in Articulatory Phonology is continuous.

Third, in Q Theory, each subsegment is internally featurally uniform. Q Theory dispenses with the Autosegmental-theoretic construct of many-to-one associations between features (or class or root nodes) and segments. As a consequence, representational structure below the segment in Q Theory is inherently and necessarily temporally sequenced. By contrast, the many-to-one feature-to-timing unit representations of Autosegmental Phonology potentially conflate the distinction between contour segments (whose subphases are sequenced in time) and complex segments (whose component features, or gestures, overlap in time). For discussion of this topic, see e.g. Sagey (1986), Lombardi (1990).

5. Three consequences of Q Theory

The remainder of this paper focuses on three consequences of Q Theory. First, Q Theory permits contrasts between segments in their internal *q* substrings. Second, it predicts that subsegments interact and can be referenced directly by the grammar. Third, Q Theory permits the notion of 'segment' to be emergent or flexible, rather than preconceived, an idea foreshadowed (with reference to Aperture nodes) by Steriade (1993, 1994).

5.1 Subsegmental contrasts

Q Theory predicts up to three featurally distinct phases in a single segment. This prediction corresponds well to contour segments like those in (6), with three internal temporal phases:

(6) *Segments with three featurally distinct ordered phases*

C(n¹ t² ʃ³)	*ⁿʧ*	prenasalized affricate
C(n¹ ʃ² h3)	*ʧʰ*	aspirated affricate
V(e̯¹ a² i̯3)	*e̯ai̯*	triphthong

For segments with only two apparent internal phases, such as simple affricates, Q Theory offers two possibilities for their internal representation, e.g. (t t ʧ) and (t ʧʧ). While probably perceptually indistinguishable in many cases and thus unlikely ever to be phonologized as a phonological contrast, this difference is manifested phonologically in several types of situations. One is identified by Pycha (2010), who points to an internal difference in timing between the stop and fricative portions of the two affricates in Hungarian: postalveolar affricates have a longer closure (relative to total duration) than alveolar affricates do (p. 146). This holds true under gemination as well, suggesting that it is a phonological distinction. In example (7), Pycha's representation of the relative timing of the closure and release components of the two affricates is translated directly into Q-theoretic representations:

(7) *Alveolar vs. post-alveolar affricates in Hungarian*

	/ts/	/ʧ/
Pycha:	[$t_x s_x$]	[$t_{xx}ʃ_x$]
Q-theory:	C(t¹s²s³)	C(t¹t²s³)

Vowels with triple tone contours present a clear case for three *q* subsegments:

(8) *Vowels with three featurally distinct ordered tones*

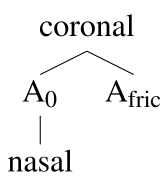
V(à¹ á² à³)	*mbǎ̂*	'owl'	Mende; Leben (1978)
V(í¹ ī² í³)	*ti₅₃₅*	'bottom'	Changzhi; Duanmu (1994)
V(é¹ è² ē³)	*bê⁻*	'tree fern'	Iau; Hyman (2009)

When two tonal targets occur on a given vowel, it is not obvious whether to represent the transition between the first two or the second two *q*'s. The likelihood that the difference could be perceptible enough to be contrastive seems low. Nonetheless, several languages do exploit this potential for contrast. According to Remijsen (2013), Bor South Dinka, like several other Dinka dialects, contrasts an early-aligned HL contour with a late-aligned HL contour. Both contours begin H and end L; the difference lies, for Q Theory, in the midde *q*. Remijsen & Ayoker (2014) report a similar contrast in Shillook.

(9) $V(H^1\ L^2\ L^3)$: Early-aligned fall
$V(H^1\ H^2\ L^3)$: Late-aligned fall

Contrasts of the type in (9) cannot be represented in Autosegmental Theory, given that the Obligatory Contour Principle (see e.g., Odden (1986)) would collapse any potential contrast among HL, HHL, HLL melodies on a single tone-bearing unit. Nor can such contrasts be represented in Aperture Theory, which posits only one subsegmental phase for approximant consonants and, by hypothesis, vowels. Of course, Aperture Theory was designed not for vowels (on which it is largely silent) but for consonants. But even setting aside the existence of diphthongs, triphthongs and tone contours that motivate segmental subdivisions within vowels, Aperture Theory does clearly predict that consonants will not exhibit more than two internal phases. This presents challenges for segments like the prenasalized affricate in (6). Recognizing that segments like ^{n}ʤ have three apparent internal phases, Steriade (1993) proposes that prenasalized affricates are represented as in (10), which would make them phonologically identical to prenasalized fricatives; Steriade suggests that affrication emerges from the phonetic "timing of the velum raising relative to the oral release (p. 413)

(10) *Prenasalized affricate in Aperture Theory*



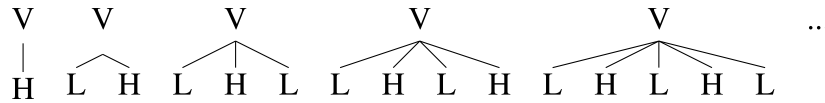
cf. $C(n^1\ d^2\ ʒ^3)$, in Q Theory

Insofar as the segment is systematically affricated, however, and insofar as there is a phonological contrast in the language between a fully oral and a prenasalized affricate, these are properties that phonological representation should encode directly, rather than relying on the phonetic component to provide. Q Theory has the representational richness to do so.

Thus far, we have seen several examples of contrasts which Q Theory can represent but Autosegmental Phonology and Aperture Theory cannot; compared to Q Theory, these approaches undergenerate subsegmental contrasts.

Autosegmental Phonology also suffers from overgeneration. This is easiest to illustrate with tone. Q Theory predicts a maximum of three tones per (short) vowel, but Autosegmental Phonology imposes no upper bound, allowing unattested contrasts like those in (11):

(11) *Predicted tone contours in Autosegmental Phonology*



In terms of their predictions regarding subsegmental contrasts, Q Theory and Articulatory Phonology are arguably the most similar in the degree to which they decompose segments into ordered phases. For example, Browman & Goldstein (1989) develop an account of intrusive [t] in Articulatory Phonology that could easily be translated into Q Theory. According to Browman & Goldstein, citing earlier proposals of Ohala (1974) and Anderson (1974), intrusive [t] emerges in what would otherwise be /ns/ clusters when overlap between the closure of the velum and the release of the tongue tip constriction produces a transitional interlude of oral closure, perceived as [t]. As Browman & Goldman observe, however, this is a variable process, dependent on speech rate and not categorically enforced by the grammar. Articulatory Phonology, with its continuously valued representations, is particularly suited to representing gradient phonetic effects. By contrast, Q Theory represents the phonologization, or discretization, of phonetic patterns. Quantal and categorical, Q Theory is designed for capturing grammatical phonological patterns that have emerged from the phonologization of gestural overlap as well as other factors. Unlike Articulatory Phonology, Q Theory can include acoustic as well as articulatory features.

5.2 Subsegmental interactivity: ABC+Q

This section discusses subsegmental independence in phonological patterning, introducing the blend of Agreement by Correspondence and Q Theory that Inkelas & Shih (2013), Shih & Inkelas (2014) term 'ABC+Q'. The focus of this section will be the role that subsegments play in capturing patterns of assimilation.

We begin with a brief review of ABC, a theory of surface correspondence in which, under conditions of (natural class) similarity and proximity, pairs of segments are compelled via CORR(espondence) contraints to correspond. IDENT constraints compel corresponding segments to agree in some specified feature(s). ABC was originally developed to account for 'long-distance' consonant harmony (Walker 2000, Hansson 2001, Rose & Walker 2004, a. o.) and has since been extended to consonant dissimilation (Bennett 2013), to vowel harmony (Sasa 2009, Rhodes 2012, inter alia), to tone (Shih & Inkelas 2014), and local segmental interactions (Inkelas & Shih 2014).

What ABC gains by incorporating Q Theory is the ability to index CORR and IDENT constraints not only to Q—i.e., the traditional segment—but also to the subsegment *q*. Constraints in ABC+Q are stated in (12).

(12) **CORR-qq**: Similar subsegments (subsegments in some natural class) correspond
qq-IDENT: Corresponding subsegments are identical, in some respect
CORR-QQ: Similar segments (segments with similar *q* sequences) correspond
QQ-IDENT: Corresponding segments are identical, in some respect

Via these constraints, ABC+Q predicts two kinds of interaction: *Q* to *Q* and *q* to *q*. In *Q* to *Q* assimilation, the entirety of a segment assimilates, in one or more features, to another. This achieves copy of contour segments (diphthongs, affricates) or of contour tones. *q* to *q* assimilation affects only subsegments and can create tonal contours or contour segments such as diphthongs or palatalized consonants.

To illustrate *Q* to *Q* assimilation, consider Hausa (13), in which stem consonants copy to filll empty C slots in affixes. Glottalized consonants (b,c) and affricates (d) copy intact, showing that contour consonants act as units. Page numbers refer to Newman (2000), and superscript letters to tone melodies imposed by the suffixes:

(13) *Hausa copy epenthesis*

a.	dámóː+ aːCeː^{HLH}	⟶	dám-àː**m**éː	'land monitor-PL' (p. 438)
b.	hás'íː+ aiCai^{HLH}	⟶	hás'-ài**s**ái	'grain-PL' (p. 437)
c.	gáɓàː+ -aːCuː^{HLH}	⟶	gáɓ-àː**ɓ**úː	'joint, limb-PL' (p. 444)
d.	gàʤéːréː+ -VCC-, -uː^{LH}	⟶	gàʤ-à**ʤ**ː-èːr-úː	'short-PL' (p. 453)

A tableau illustrating how correspondence constraints work in ABC+Q to induce copy epenthesis at the *Q* level is presented below. This example involves a copied glottalized *s'*. In production, Hausa glottalized fricatives tend to have an initial stop component; in orthography they are represented as "ts". (Lindsey et al. (1992) report that 'In our data, a silent interval not only follows the frication but also precedes it, which we take as an indication of a genuine affricate' (p. 519).) The *Q*-theoretic representation (ʔ s ʔ) reflects both this initial silent component and the release of the oral constriction prior to that of the glottal constriction, yielding a 'post-glottalized' or ejective consonant.

In the tableau in (14), winning candidate (a) shows correspondence and *Q*-level identity between the root-final and suffix consonant. In losing candidate (b), both consonants also correspond and are identical, but both are reduced to the unmarked consonant, ʔ, violating IDENT-IO. Losing candidate (c) violates CORR-CC and loses to candidate (a). General markedness penalizes glottalized segments.

(14) *Copy epenthesis in ABC+Q*

	/há(ʔ s' ʔ)íː+ aiCai^{HLH}/	IDENT-IO	CORR-CC	CC-IDENT	MARKED-NESS
☞ a.	há(ʔ s' ʔ)$_i$ài(ʔ s' ʔ)$_i$ái				(2)
∼ b.	há(ʔ ʔ ʔ)$_i$ài(ʔ ʔ ʔ)$_i$ái	W(1∼0)			L(0∼2)
∼ c.	há(ʔ s' ʔ)ài(ʔ ʔ ʔ)ái		W(1∼0)		L(1∼2)
∼ d.	há(ʔ s' ʔ)$_i$ài(ʔ ʔ ʔ)$_i$ái			W(1∼0)	L(1∼2)

Q to *Q* harmony also occurs in tonal domains; for example, the whole-contour tone copy in Changzhi, discussed by (Yip 1989, Bao 1990, Duanmu 1994), is analyzed as *Q* to *Q* tone agreement in Inkelas & Shih (2013), Shih & Inkelas (2014).

In contrast to the whole-segment assimilation of *Q* to *Q* harmony, *q* to *q* harmony produces partial assimilation. An example in the segmental domain, namely partial assimilation in nasality of an oral consonant to an adjacent nasal vowel, is illustrated in (15) for Mbya (Thomas 2014, p. 85-86).

(15) *Consonant prenasalization in Mbya*

a.	ãˈkã + ˈka →	ãˈkã-ᵑga	‘head + ‘hit’ = ‘head hitting’
b.	ava-ˈkʷe		‘men’
	kũɲã-ˈᵑgʷe		‘women’

An illustrative tableau is provided below. (The constraints responsible for the full voicing of the prenasalized consonant are not given here, for reasons of space.)

(16) *Prenasalization in ABC+Q*

	/...ã-k.../	CORR-v::c	vc-IDENT-[nas]	IDENT-IO[nas]
☞ a.	(ã ã ã$_i$)(ŋ$_i$ g g)			(1)
∼ b.	(ã ã ã)(k k k)	W(1∼0)		L(0∼1)
∼ c.	(ã ã ã$_i$)(k$_i$ k k)		W(1∼0)	L(0∼1)
∼ d.	(ã ã ã$_i$)(ŋ$_i$ ŋ ŋ)			W(3∼1)

As discussed in Inkelas & Shih (2013), Shih & Inkelas (2014), *v* to *v* correspondence can produce tone contours, as in Yoruba (Akinlabi & Liberman 2001) or Haya (Hyman 2007:20), where part of a vowel assimilates in tone to another. Q Theory can also capture tonal contours arising from partial assimilation of a vowel to a consonant, as for depressor consonants (see, e.g., Bradshaw (1999)).

Q theory employs *q* to *q* correspondence to capture dipthongization processes such as those discussed by Hayes (1990); we illustrate here with vowel breaking in San Francisco del Mar Huave (17). When a vowel and following coda consonant disagree in palatality, the vowel ‘breaks’ so that its final *q* agrees with the [back] specification of the consonant (Kim 2008). This is *v* to *c* correspondence.

(17) *Vowel breaking in Huave*

	Non-palatal C	Palatal C
Back V	sap	sap^{pal} → s**ai**p
Front V	mik → m**io**k	pek^{pal}

An ABC+Q analysis of *q* to *q* correspondence is presented in (18), for Huave. CORR-[v::c]$_\sigma$, compels *q* to *q* correspondence between tautosyllabic, adjacent *v* and *c* subsegments. qq-IDENT[pal] compels agreement in palatality:

(18) *Vowel breaking in Huave: ABC+Q analysis*

	V(a a a)C(p^{pal} p^{pal} p^{pal})	CORR-[v::c]$_\sigma$	qq-IDENT[pal]	IDENT-IO
☞ a.	V(a a i_i)C($p^{pal}{}_i$ p^{pal} p^{pal})			(1)
∼ b.	V(a a a)C(p^{pal} p^{pal} p^{pal})	W(1∼0)		
∼ c.	V(a a a_i)C($p^{pal}{}_i$ p^{pal} p^{pal})		W(1∼0)	
∼ d.	V(i i i_i)C($p^{pal}{}_i$ p^{pal} p^{pal})			W(3∼1)

Standard, segment-based ABC (without *q*) has difficulty accounting for contour formation. As shown in (19), segment-to-segment correspondence, e.g CORR-V::C, cannot compel segment contouring, since a contour output (a) violates VC-IDENT[pal] to the same extent as the fully faithful candidates with (c) and without (b) correspondence. The intended winner, (a), is harmonically bounded by (c), so can win on no ranking of the constraints.

(19) *Standard ABC has trouble with contour formation:*

	/...ap^{pal}/	CORR-V::C	VC-IDENT[pal]	IDENT-IO
☞ a.	$a^j{}_i p^{pal}{}_i$		(1)	(1)
☜ b.	ap^{pal}	1		
c.	$a_i p^{pal}{}_i$		1	
d.	$i_i p^{pal}{}_i$			2

In sum, contour formation as a result of assimilation shows that ABC needs to refer to the individual, sequenced portions of contour segments. Subsegmental representations allow ABC to describe subsegmental assimilation and predict that subsegmental assimilation will share the similarity bases and proximity generalizations that drive segmental assimilation.

6. Q's about Q Theory

Having seen that Q Theory can handle segmental and subsegmental assimilation patterns, we now step back and raise a number of questions that will guide future work on Q Theory.

1. Does every *Q* have to have 3 *q*'s? Despite the assumption in the previous sections that each *Q* has 3 *q* subsegments, this is not a necessary plank of Q Theory. Positing a smaller number of vocalic subsegments could be phonologically motivated in languages without diphthongs or contour tones, or as a way of distinguishing full vowels and consonants from transitional schwas and intrusive consonants. For example, the transitional schwa in the /tb/ cluster of *katb* [$kat^ə b$] 'to write' in Moroccan Colloquial Arabic (Gafos 2002:278), might merit only a single subsegment. The ambisyllabic behavior of flap in American English (Kahn (1976), Gussenhoven (1986); see also Derrick et al. (2015)) could be modeled by assigning a flap only two subsegments and denying it a target closure subsegment. Contextual elimination of subsegments, as Steriade (1993, 1994) suggests for release nodes in Aperture Theory, also produces nonmaximal segments.

2. Must every *q* be featurally specified? Like traditional segments, *q* subsegments may be underspecified if warranted. In any segment, the first and last *q* are most prone to coarticulation with neighboring segments. Underspecification of edge subsegments is one way of permitting gradient interpolation from one target q^2 to another. For example, V(i i I)CV(I u u) (where 'I' represents a high vowel unspecified for [round]), or V(L L ∅)V(H H H) (where '∅' represents a vowel unspecified for tone), could represent anticipatory coarticulation between consecutive q^2 targets. (An alternative encoding of coarticulation would be the use of subfeatures, as proposed by Lionnet (2014, this volume).)

3. How internally diverse can *Q*'s be? A fundamental question for future research concerns the upper bound of diversity among the *q* subsegments in a given *Q*. Steriade (2014), speculating on how Q Theory might prevent an internally heterogeneous string of subsegments like (r o p) from being represented as a single *Q*, suggests "a mutual compatibility condition on the set of features belonging to one segment: they must correspond to a set of potentially simultaneous articulatory gestures. This allows *nʧ(h), (ʔ)nʧ*, but not *rop, kis, i̯u̯ai*." This suggestion, however, is too strict, as it excludes sequenced incompatible features, like tone contours on short vowels, or nasal-oral subphases of a consonant. An alternative approach would be to view *Q*'s as emergent, comprising a string of *q*'s that is internally more featurally similar than any other 3-*q* string that any of those *q*'s might be parsed into. On feature-driven similarity, see e.g. Wayment (2009).

A related question concerns the *lower* bound of diversity that a given *Q* can tolerate. Q Theory might overpredict contrasts if it permits a language to distinguish, say, C(t d t) from C(t t t), or V(i i i) from V(i ɨ i). The more elements of representation, the more potential contrasts exist. Of course, the problem of contrasts that can be represented phonologically but are not utilized is well-known and has solutions, e.g. Steriade's (2001) P-Map which prohibits insufficiently perceptible contrasts in grammar (see also Silverman (1997), p. 46).

4. Clusters: *Q* or *q*? Q Theory brings to the forefront a perenially lurking question in phonological theory, namely whether and how to distinguish clusters and contour segments. In English, for example, *ts* is considered a consonant cluster (*cats, Ritz*, etc.), while the affricate *ʧ* (*catch, rich*, etc.) is considered a single segment. In Q Theory, the representational difference is stark: /ts/ = (t t t)(s s s), while /ʧ/ = (t t ʃ). Yet acoustically and articulatorily the two are similar. A potential solution to this problem of overdifferentiation lies in the proposals by Steriade (1993, 1994) and Gafos (2002) regarding trapped transitions. In a cluster like English /ts/, the tongue does not return to a neutral position after articulating /t/ and before commencing the articulation of /s/. Rather, the release of /t/ and the onset of /s/ overlap. The appropriate Q representation of /ts/ is more like that for an affricate: (t t t)(s s s) → (t t)(s) (or simply (t t s)).

5. Length. A final challenge for future work in Q Theory involves length. The standard phonological approach to length is inherently autosegmental: a single feature bundle is associated with two timing units. It is certainly possible to retain this approach under Q Theory: a single *Q* could be either monomoraic or bimoraic. But Q Theory also introduces the possibility of lengthening through subsegmental accretion, or shortening through subsegmental deletion. How tightly (if at all) to connect subsegmental quantity with phonetic duration and/or phonological length contrasts is a compelling question for future research.

7. Conclusion

The aim of this article is to stake out the position that subsegments act independently and need to be independently referenced by the phonological grammar. Strictly segmental theories, from SPE to standard ABC, lack the ability to refer to subsegments. Autosegmental Phonology, Aperture Theory and Articulatory Phonology are all steps in the right direction; Q Theory builds on all three, bringing together their key insights in a single formalism. ABC+Q, the marriage of Q Theory and ABC, has the descriptive power to model subsegmental behavior and thus to capture the phonological patterning of diphthongs, contour tones, and other contour segments.

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