Articulator-free Features and Sound Classes*

San Duanmu
duanmu@umich.edu

2019

(Draft: comments welcome!)

Abstract

An articulator-free feature is one that can be performed by two or more articulators, such as [stop], which can be performed by the tongue tip in [t] or the tongue body in [k]. Articulator-free features, which include most manner features, have played a prominent role in feature theory, both in representing consonants and in defining sound classes ('natural classes'). However, when features are interpreted as gestures of active articulators, articulator-free features are called into question. In the gestural interpretation, it can no longer be taken for granted that similar gestures performed by different articulators, such as Tip-[+stop] and Lip-[+stop], are identical, unless articulator-free gestures can define sound classes. In this study, I examine sound classes in Kennedy (2016) in order to determine whether articulator-free features are necessary. It is found that all sound classes can be defined without articulator-free features. The result supports a gestural interpretation of features and simplifies feature theory.

Keywords: phonological features; articulators; articulatory gestures; articulator-free; articulator-bound; manner features; sound class;

1. Two types of features: articulator-bound and articulator-free

A distinction is often made between consonants and vowels. A vowel is articulated with no obstruction in the vocal tract and a consonant is articulated with an obstruction. On this view, a long tradition in defining consonants is to focus on where the obstruction is and how the obstruction is made, known as the 'place' and the 'manner' of articulation respectively. In the consonant chart of the IPA, manner features are listed in the first column and place features in the first row. A consonant is, therefore, represented with three features, a place feature, a manner feature, and a feature for voicing. Some examples are given in (1).

(1) Representing consonants in IPA features

Consonant	Place	Manner	Voicing
[p]	labial	stop	voiceless
[b]	labial	stop	voiced
[t]	alveolar	stop	voiceless
[s]	alveolar	fricative	voiceless

A typical place feature is specific to one articulator. For example, closures made at the 'alveolar' place are made by the tongue tip, and closures made at the 'velar' place are made by the tongue body. In contrast, a typical 'manner' feature is not specific to one articulator but can be made by two or more articulators. For example, [stop] can be made by the tongue tip or the

tongue body. Halle (1992; 1995) introduces two terms, rephrased in (2), to distinguish the two types of features.

(2) Two types of features (Halle 1992; 1995)
If a feature can be made by only one articulator, it is 'articulator-bound'.
If a feature can be made by two or more articulators, it is 'articulator-free'.

In Halle's definition, most place features are articulator-bound and most manner features are articulator-free. In the 2018 edition of the IPA chart, there are six manner features, shown in (3), where 'plosive' is also called 'stop'. I have merged 'lateral fricative' with 'fricative' and 'lateral approximant' with 'approximant'.

(3) Manner features in the 2018 consonant chart of the IPA
Plosive (stop)
Nasal
Trill
Tap or Flap
Fricative
Approximant

In what follows, I shall focus on four manner features: stop, fricative, nasal, and approximant, since they cover most consonants. I shall also discuss 'major class' features, such as [consonant] and [sonorant], which are also articulator-free.

2. Manner features and sound classes

Besides their role in defining consonants, manner features are often used in defining sound classes. A sound class, also called a 'natural class', is a set of sounds that behave the same way in a phonological rule or process. The general notation of a rule is shown in (4) and an example in English is shown in (5), where # represents a word boundary.

(4) Phonological rule and sound classes
General notation: A → B / C__D
Sound classes: A (target)
C (trigger)
D (trigger)

(5) Aspiration of [p t k] in English
In IPA: [p t k] → [p^h t^h k^h] / #__ V
In features: [+stop, -voice] → [+stop, -voice, +aspirated] / #__ [+syllabic]

According to Mielke (2008), each rule involves up to three sound classes (which he calls 'phonologically active classes'): A, C, and D in the general notation. He calls A the 'target' of the rule and C and D the 'trigger' of the rule. In the English example, the target is [p t k], definable as [+stop, -voice], and the trigger is the set of vowels, definable as [+syllabic]. Mielke

does not consider B to be a sound class, probably because its members are not always contrastive in a given language. I shall follow Mielke and assume that triggers and targets of phonological rules are sound classes. Most sound classes, if not all, are definable by a set of features. In addition, many sound classes have been defined with one or more manner features.

3. Gestural features

Phonological features are used for three purposes: (i) describing how a sound is made; (ii) representing contrast; and (iii) defining sound classes. Features for (i) are mostly based on articulation. Features for (ii) and (iii) can be based on articulation, acoustic or auditory properties, or completely abstract notions. Some examples are shown in (6).

(6) Articulatory and non-articulatory features

Property	Sample features
Articulatory	[high], [back], [labial]
Acoustic	[strident], [voice], [sonorant]
Auditory	[high], [sonorant], [syllabic]
Abstract	[tense]

Among articulatory features, [high] and [back] for vowels are based on gestures of the tongue, and [labial] refers to the use of the lips (or the lower lip). Among acoustic features, [strident] refers to the presence of strong noise, [voice] refers to a periodic waveform, and [sonorant] refers to high intensity. Among auditory features, [high] of tone refers to perceived pitch level, not necessarily of a fixed frequency or frequency range; [sonorant] refers to perceived loudness; and [syllabic] refers to a perceived presence of a syllable. The feature [tense] is used to distinguish certain vowel pairs, such as [i] and [ɪ] in English, but it is hard to describe it in articulatory, acoustic, or auditory terms. Therefore, Ladefoged & Johnson (2011: 300) consider [tense] to be an abstract feature, devoid of phonetic correlates.

Since most feature theories assume at least some articulatory features, the simplest approach is to define all features in articulatory terms. In addition, because articulation is an action, which involves articulators and their gestures, the simplest approach is to define every feature this way. The proposal is shown in (7) and (8). It has been called 'articulator-based' feature theory (McCarthy 1991). I shall refer to such features as 'gestural features'.

(7) Gestural features

a. A feature is a gesture of an active articulator.
b. An active articulator is a moveable part in the vocal tract.

(8) Active articulators and their gestures

Articulator	Sample gesture
Lip (or 'lower lip', 'lips')	[round]
Tip (of the tongue)	[lateral]
Body (of the tongue)	[high]
Velum	[lowered] ([nasal])

Root (of the tongue)	[advanced]
Glottis	[slack (vocal folds)] ([voiced])
Larynx	[raised]

The gesture [round] is made by Lip. The feature [lateral] is made by Tip. The gesture [high] (of a vowel) is made by Body. The gesture [lowered] is made by Velum. The gesture [advanced] is made by Root. The gesture [slack] (of the vocal folds) is made by Glottis. The gesture [–raised] is made by Larynx. Some gestures have a more common term, such as [nasal] (for [lowered] of Velum) and [voice] (for [slack] of Glottis). For ease of reading, I shall continue to use familiar terms like [voice] and [nasal], although they refer to acoustic effects and do not directly tell us what the gestures are.

Gestural features have been proposed by Sagey (1986), Browman & Goldstein (1986; 1989; 1992), Ladefoged & Halle 1988, and Halle (1992; 1995). In addition, Duanmu (2016), proposes that seven active articulator are sufficient to represent all contrasts in any language. In (9) and (10), I compare the representation of [p t k] in traditional features and in gestural features.

(9) Representing [p t k] in traditional features

[p]	[+labial, +stop, -voice]
[t]	[+alveolar, +stop, -voice]
[k]	[+velar, +stop, -voice]

(10) Representing [p t k] in gestural features

[p]	Lip-[+stop]
	Glottis-[-voice]
[t]	Tip-[+stop]
	Glottis-[-voice]
[k]	Body-[+stop]
	Glottis-[-voice]

In the traditional representation, every label is a feature. In the gestural representation, some traditional features correspond to articulators, directly or indirectly, while other features correspond to gestures. For example, the traditional feature [labial] has become the articulator Lip, and the traditional feature [alveolar] is reinterpreted as using the Tip. Traditional features [stop] and [voice] are now gestures of their own articulators.

As discussed earlier, [voice] is articulator-bound, because it is performed by Glottis only. In contrast, [stop] is articulator-free, because it can be performed by Lip, Tip, or Body, so is [fricative]. Also of interest is [nasal]: while it has been called a manner feature, it is articulator-bound, because it is it a gesture of Velum only. Apart from [nasal], all manner features can be represented as a combination of [stop] and [fricative]. This is shown in (11), where all manner features (except [nasal]) are articulator-free. In addition, major class features, such as [consonant] and [sonorant], are also articulator-free.

(11) Representing manner features with [stop] and [fricative] only

Manner	Example	Features
Stop	[t]	Tip-[+stop, -fricative]
Fricative	[s]	Tip-[-stop, +fricative]
Approximant	[r]	Tip-[-stop, -fricative]
Affricate	[ts]	Tip-[+stop, +fricative]

Articulator-free features raise a theoretical question for feature theory: When a gesture is performed by different articulators, is it still the same gesture? For example, are the two gestures in (12) the same?

(12) Are the following gestures the 'same'?
Lip-[+stop]
Tip-[+stop]

In one sense, the two gestures are different, because they have different articulators. On the other hand, the representations share the label [stop], which implies that the gesture is the same in the two representations. However, similar gestures need not be given the same label, unless there is independent evidence for it. For illustration, consider the features in (13), which are commonly seen in the literature.

(13) Similar gestures not labeled the same way

Feature	Gesture
[protruded]	forward movement of Lip
[anterior]	forward movement of Tip
[front]	forward movement of Body
[advanced]	forward movement of Root

All the gestures involve a forward movement, as the terms 'protruded', 'anterior', 'front', and 'advanced' indicate. Why then are they not given the same feature term, such as 'fronted' or 'forward'? The reason seems to be that there is no evidence that this set of gestures behave the same way; for example, there is no evidence that sounds with this set of gestures can form a class in a phonological rule. By the same reasoning, it is insufficient to say that, because the closure gestures in [p t k] have something in common phonetically (they all shut off the airflow in the oral tract), [p t k] must be given the same feature [stop]. Instead, the justification should be based on phonological evidence, especially whether [stop] can define a sound class, regardless of the articulators. Without such evidence, we should not label the closure gestures in [p t k] with the same term, so as not to imply that they are the same gesture or that they can define sound classes.

4. Verifying articulator-free features in English

I begin with sound classes in English in order to find out whether there is preliminary evidence for articulator-free features. Ladefoged & Johnson (2011) list nineteen rules for consonants and six rules for vowels. However, only one of the rules seems to involve an articulator-free feature.

We have seen the rule in (5), by which [p t k] are aspirated in word-initial position. The feature of interest is [stop], which is used to define the class [p t k]. Let us consider whether it is possible to state the rule without using [stop]. We begin with the gestural representation of [p t k], repeated in (14).

(14) Representing [p t k] in gestural features

[p]	Lip-[+stop]
	Glottis-[-voice]
[t]	Tip-[+stop]
	Glottis-[-voice]
[k]	Body-[+stop]
	Glottis-[-voice]

The only gesture completely in common among [p t k] is Glottis-[-voice]. If we use this feature to define the target class, the rule is as in (15).

(15) The aspiration rule in English, without using articulator-free [stop]
Glottis-[-voice] → Glottis-[-voice, +aspirated] / #__

The class defined by Glottis-[-voice] includes not just [p t k] but all voiceless consonants. The question is whether this rule can work properly. The set of voiceless English consonants are [p t k f θ s ʃ h ʧ] and the rule predicts that they are all aspirated in word-initial position. We know that [p t k] are, so is [h]. It can be argued, too, that, even though its aspiration is not transcribed, [ʧ] is in fact aspirated, because the English [ʧ] is similar to the aspirated [tɕʰ] in Chinese, rather than the unaspirated [tɕ]. The remaining sounds are the fricatives [f θ s ʃ]. It can be argued that they are all aspirated as well. For example, the aspiration of the English [s] is similar to that in the aspirated [tsʰ] in Chinese, rather the unaspirated [ts]. Thus, the new rule works just as well as the old one, although it applies vacuously to [f θ s ʃ h ʧ], which are already aspirated.

A comment on the trigger of the rule is also in order. In (5), the rule applies before vowels, but in (15), there is no such requirement. The reason is that, besides vowels, word-initial [p t k] can also be followed by the approximants [l r w j]. In the latter case, [p t k] are aspirated as well, although the aspiration is realized over the devoiced [l r w j]. In any case, it is not impossible to define the class of vowels, as we shall see below. In summary, as far as English is concerned, there is no need for articulator-free features.

5. Additional verification

Let us now consider sound classes in other languages. To cover a reasonably representative set of data within the available space, I have chosen the sound classes in Chapter 5 (Phonemic analysis) and Chapter 6 (Natural classes and distinctive features) of Kennedy (2016), a textbook in phonology. The data include over fifty rules from eighteen languages. Kennedy frequently uses articulator-free features to define sound classes. However, I shall show that all of the sound classes are definable without articulator-free features. For each relevant case, I shall assume that Kennedy's rule is descriptively accurate, before considering whether it can be restated without using articulator-free features for the trigger class or the target class.

We begin with a rule in Catalan (Kennedy 2016: 133-136), shown in (16), where voiced obstruents (stops and fricatives) are devoiced in word-final position.

(16) Obstruent devoicing rule in Catalan

Consonants:	[p t k kʷ b d ɡ ɡʷ f s ʃ v z ʒ m n ɲ r l ʎ w j]
In IPA:	[b d ɡ ɡʷ v z ʒ] → [p t k kʷ f s ʃ] / __ #
Kennedy:	[+voice, -sonorant] → [-voice, -sonorant] / _ #
New rule:	Glottis-[+voice] → Glottis-[-voice] / _ #

The rule in IPA does not tell us what makes [b d ɡ ɡʷ v z ʒ] a class. The rule given by Kennedy (2016: 136) defines the input class as [+voice, -sonorant], where [sonorant] is an articulator-free feature. The new rule, in gestural features, does not use [sonorant]. The question is whether it can make correct predictions. A look at the consonant inventory shows that [voice] is contrastive between [p t k kʷ f s ʃ] and [b d ɡ ɡʷ v z ʒ] but not for [m n ɲ r l ʎ w j]. In the theory of underspecification (Steriade 1987; Archangeli 1988; Keating 1988), non-contrastive features need not be specified. If [voice] is unspecified for [m n ɲ r l ʎ w j], then Glottis-[+voice] only refers to [b d ɡ ɡʷ v z ʒ], as desired.

Next we consider a rule in Cuzco Quechua (Kennedy 2016: 149-151), where [x χ] becomes [k q] before a vowel. The rule is shown in (17).

(17) A rule in Cuzco Quechua

In IPA:	[x χ] → [k q] / __ vowel
Kennedy:	[DORSAL, -stop] → [DORSAL +stop] / __ [+syllabic]
New rule:	Body-[-stop] → Body-[+stop] / __ <peak>

The rule by Kennedy (2016: 151) is quite similar to the new rule in gestural features, where Dorsal corresponds to the articulator Body. Both rules use the feature [stop], but since [stop] in this rule is limited to just one articulator (Body), its use is no argument for articulator-free features in general. Kennedy's rule also uses the feature [+syllabic], which refers to a vowel. However, [syllabic] is not an articulatory gesture and it is better to avoid it. Phonologically, a vowel occupies the 'peak' (or the nucleus) of a syllable. Therefore, we can refer to vowels by their position in a syllable, with the notation '<peak>'. A final comment is that the difference between velar and uvular consonants is that the latter have an extra feature Root-[-advanced], which is unaffected by the rule, and by convention it is not shown.

Next we consider a rule in Karo (Kennedy 2016: 99-100), which changes voiceless stops to voiced ones when they occur between vowels. The rule is shown in (18), along with the consonant inventory of Karo, from P-base (Mielke 2004-2007).

(18) Voicing of stops in Karo

Consonants:	[p t ʧ k b d ʤ ɡ s h m n ŋ l r w j]
In IPA:	[p t ʧ k] → [b d ʤ ɡ] / V__ V
Kennedy:	[-voice, +stop] → [+voice, +stop] / V__V
New rule:	Glottis-[-voice] → Glottis-[+voice] / <peak>__<peak>

The rule adapted from Kennedy (2016: 100) defines the input class as voiceless stops (I have converted Kennedy's [-continuant] to the more familiar term [+stop]), where [stop] is

articulator-free, since it refers to different articulators. The new rule works just as well without reference to [stop]. The reason, again, is that [voice] is contrastive only between [p t ʧ k] and [b d ʤ g], whereas other consonants are unspecified for [voice]. Therefore, the rule will only apply to [p t ʧ k], as desired.

Next we consider two rules in Cambodian that apply to an initial CC cluster. One inserts [ə] between the consonants, if the initial consonant is a sonorant. The other rule makes the initial C aspirated, if it is a voiceless stop. Other than the above two cases, initial C or CC remain unchanged. The descriptive data are summarized in (19)-(21), from Kennedy (2016: 130-133), along with the consonant inventory in (22), from P-base.

(19) [ə]-insertion in Cambodian
Shorthand: 0 → [ə] / #C__CV
Kennedy: 0 → [ə] / #[+sonorant, +consonant] __ [+consonant]
Clusters: [mc mr mh lŋ lh lm mt mŋ mn ml ms]

(20) Aspiration of voiceless initial C in Cambodian
Shorthand: C → C^h / #__CV
Kennedy: [+stop, -voice] → [+aspirated]/ #__ +stop]
Clusters: [p^ht p^hk $p^hɲ$ t^hp t^hm $t^hŋ$ c^hp c^hm $c^hŋ$ k^ht k^hm $k^hɲ$ p^hc p^hn $p^hŋ$ t^hk t^hn c^hn k^hc k^hn]

(21) Permitted initial C or CC in Cambodian
[p^h t^h c^h k^h pr tr cr kr ps ks]
[sp sk sn sŋ sl sm sɲ sr]

(22) Consonant inventory in Cambodian (Mielke 2004-2007)
[p t c k ʔ b d f s h v ʒ m n ɲ ŋ r l]

The rule in (19) uses the articulator-free features [sonorant] and [consonant] to define the trigger class. Similarly, the rule in (20) uses the articulator-free feature [stop] to define the trigger class and the target class. As an alternative, I propose the analysis in (23).

(23) Alternative analysis of the Cambodian data
- The syllable onset has only one position, filled by a regular C or a complex C.
- Insert [ə] after an unsyllabified C in word-initial position.
  0 → [ə] / #<X>__<onset>
- Voiceless C is aspirated in word-initial position.
  [-voice] → [-voice, +aspirated] / #__
- After an aspirated C, [ə] is devoiced.
  [ə] → [-voice] / [+aspirated] __

In the [ə]-insertion rule, I use <X> to refer to an unsyllabified sound. Because vowels are always syllabified as the peak of a syllable, <X> in effect refers to an unsyllabified consonant.

Also, <onset> refers to a sound in the syllable onset position, which is a consonant, too. Thus, none of the rules makes use of articulator-free features.

In (21), [pʰ tʰ cʰ kʰ] are single sounds and [pr tr cr kr ps ks] are possible complex sounds; therefore, [pʰ tʰ cʰ kʰ pr tr cr kr ps ks] can fit in the onset position. A complex sound is one whose gestures can be made simultaneously (Duanmu 2016). For example, the gesture for [p] and that for [s] use different articulators, which allows them to be performed simultaneously. Similarly, the gestures for [p] and [r] can be performed simultaneously. Therefore, no [ə]-insertion is needed for this set of onsets.

The set of clusters in (19) and (20) are not possible complex sounds. For example, in [mt], [m] is [+nasal] and [t] is [-nasal], and the two contradictory gestures cannot be made simultaneously, but has to be made sequentially. Similarly, in [tn], [t] is [-nasal] and [n] is [+nasal], and the two gestures cannot be made simultaneously either. The clusters [sp sk sn sŋ sl sm sɲ sr] in (21) are not possible complex sounds either. If the Cambodian onset has just one position, the initial C in the clusters of (19) and (20), and the initial [s] of [sp sk sn sŋ sl sm sɲ sr] in (21), are all unsyllabified, after which the [ə]-insertion rule will apply.

Next we consider aspiration. In the present analysis, aspiration applies to not just initial voiceless stops, but all initial voiceless consonants. This means that not only will initial [p t c k] be aspirated, but initial [s] will as well, which I shall elaborate on shortly. Unfortunately, the data in Kennedy (2016) do not contain initial [f h ʔ], so we cannot verify their behavior.

Finally, we consider [ə]-devoicing after an aspirated C. This rule is well motivated and occurs in English as well, such as *potato* → *p'tato*, *tomato* → *t'mato*, *Canadian* → *C'nadian*, *suppose* → *s'ppose*, and *Toronto* → *Tronto*. The lack of a fully pronounced vowel also makes the transcription somewhat ambiguous. For example, it is not easy to tell whether *p'tato* is [pʰə̥tʰeɾo] (with a devoiced [ə̥]) or [pʰtʰeɾo] (without a devoiced [ə̥]) in American English, and there is unlikely to be a contrast between such pairs in any language.

In (24), I illustrate the full analysis, with two examples from each type, where [0] represents a devoiced [ə̥] in the output. The ordering of the rules is not crucial and does not affect the result of the present analysis.

(24) Illustration of initial C and CC in Cambodian

Input	[mh lŋ]	[pt pn]	[p pr]	[sʰp sʰn]
[ə]-insertion	[məh ləŋ]	[pət pən]	--	[sʰəp sʰən]
Aspiration	--	[pʰət pʰən]	[pʰ pr̥]	--
[ə]-devoicing	--	[pʰə̥t pʰə̥n]	--	[sʰə̥p sʰə̥n]
Output	[məh ləŋ]	[pʰ0t pʰ0n]	[pʰ pr̥]	[sʰ0p sʰ0n]

In [mh lŋ], the initial C is unsyllabified but not voiceless. Therefore, [ə]-insertion applies but aspiration and [ə]-devoicing do not. In [pt pn], the initial [p] is unsyllabified and voiceless. Therefore, [ə]-insertion, aspiration, and [ə]-devoicing all apply. The output [pʰ0t pʰ0n] is similar to [pʰt pʰn] in the original transcription. In [p pr], the initial [p] is syllabified and voiceless. Therefore, [ə]-insertion does not apply but aspiration does. In [pr] the aspiration is likely realized as a voiceless [r̥], similar to the case in English. The output is [pʰ pr̥], where [pr̥] is likely to be a more accurate transcription than the original [pr]. In [sp sn], the initial [s] is unsyllabified and

voiceless. In addition, as I suggested earlier, it can be argued that [s] is aspirated, as voiceless fricatives usually are, although they are not transcribed with aspiration. Therefore, [ə]-insertion, aspiration, and [ə]-devoicing all apply, although aspiration yields no effect, since [s] is already aspirated. The output [s^{h}0p s^{h}0n] is similar to [s^{h}p s^{h}n], which is transcribed as [sp sn] in the original data.

Next, let us consider a rule in Persian (Kennedy 2016: 115-116), by which [r] becomes a flap when it occurs between vowels. The rule is given in (25).

(25) An allophonic rule in Persian
Kennedy: [r] → [ɾ] / V__V
New rule: Tip-[+trill] → Tip-[+flap] / <peak> __ <peak>

There are two points of interest. First, [trill] and [flap] are often listed as manner features; in this rule, however, they are limited to the articular Tip and do not constitute evidence for articulator-free features in general. Second, Kennedy's rule uses the symbol V for vowels. In the new rule, V is interpreted as a position in the peak of a syllable.

Next, let us consider a rule in Malay (Kennedy 2016: 139-142), which deletes a voiceless consonant after a nasal. The rule is given in (26).

(26) Consonant deletion in Malay
Kennedy: [+consonant, -voice] → 0 / [+nasal, +consonant] __
New rule: Glottis-[-voice] → 0 / Velum-[+nasal] __

Kennedy's rule uses the articulator-free [+consonant]. In the new rule, [consonant] is not needed, since it is entirely redundant. It is also worth noting that the rule deletes not just one or two features, but the entire consonant that contains such features. In other words, the rest of the features in the input consonant are not written. A full representation of the rule is as in (27), where parentheses indicate articulators that may or may not be present in the input consonant, and '…' indicates whatever feature there may be under each of the articulators.

(27) A full representation of consonant deletion in Malay, in gestural features
Glottis-[-voice] → 0 / Velum-[+nasal] __
(Lip-[…])
(Tip-[…])
(Body-[…])

Next we consider another rule in Malay (Kennedy 2016: 139-142), which changes [ŋ] to the same place as the following consonant. The rule is given in (28).

(28) Place assimilation of [ŋ] in Malay

Kennedy:	ŋ → [x place] /__ [+consonant, x place]		
New rule:	Velum-[+nasal] →	Velum-[+nasal] / __	<onset>
	Body-[+stop]	(Lip-[+stop])	(Lip-[…])
		(Tip-[+stop])	(Tip-[…])
		(Body-[+stop])	(Body-[…])

The rule is from Kennedy (2016: 141) uses the articulator-free feature [consonant]. In addition, it uses a variable notation [x place], which means 'same place as'. In the new rule, [+consonant] is replaced by a syllable position <onset>. In addition, [x place] is spelled out as any of three articulators (Lip, Tip, or Body). Thus, the new rule uses no articulator-free feature for the trigger class.

Next we consider a rule in Baghdadi Arabic (Kennedy 2016: 142-145), which changes the definite article [l] to the following consonant, if the latter uses Tip. The rule is given in (29), where [cons] is [consonant], COR is 'coronal' (the use of Tip), and [lat] is [lateral].

(29) [l] assimilation in Arabic

In IPA:	[l] → [t s z θ ðˤ n ʃ tˤ sˤ d ʃ ð r l ʤ] / __ [t s z θ ðˤ n ʃ tˤ sˤ d ʃ ð r l ʤ]			
Kennedy:	[+cons, COR] →	[+cons, COR, -lat] / __		[+cons, COR, -lat]
		[α anterior]		[α anterior]
		[β distributed]		[β distributed]
		[γ sonorant]		[γ sonorant]
		[δ continuant]		[δ continuant]
		[ϵ nasal]		[ϵ nasal]
New rule:	Tip-[+lateral] →	Tip-[α …]	/ __	Tip-[α …]
		(Body-[β …])		(Body-[β …])
		(Root-[γ …])		(Root-[γ …])
		(Velum-[δ …])		(Velum-[δ …])
		(Glottis-[ϵ …])		(Glottis-[ϵ …])

A few comments can be made of the rule proposed by Kennedy (2016: 144). First, it assumes that [l] does not change before [l], which is an unnecessary assumption. Second, the rule fails to show that [l] assimilates in voicing to the following consonant. Third, the rule fails to show that [l] assimilates in pharyngealization to the following consonant. Of interest is the set of variables 'α', 'β', 'γ', 'δ', and 'ϵ' before each relevant feature; they indicate that [l] 'changes to the same value as' each relevant feature. The variable notation is used in the new rule, too, although in a slightly different way: each variable represents a set of feature values under a given articulator, rather than the value of a single feature. For example, for [θ], Tip-[α…] means Tip-[+front, +fricative, -stop], where [+front] is interpreted as 'interdental' (Tip is fronted). Once again, there is no need to specify any articulator-free feature.

Next we consider a spirantization rule in Catalan (Kennedy 2016: 134-139), which changes [b d g ʤ] to fricatives. The rule is given in (30). In traditional features, [-continuant, -sonorant] is an oral stop and [+continuant, -sonorant] is a fricative.

(30) Spirantization in Catalan

Consonants:	[p t k kʷ b d g gʷ f s ʃ v z ʒ m n ɲ r l ʎ w j]	
In IPA:	[b d g ʤ] → [β ð ɣ ʒ] / V__V	
Kennedy:	[+voice, -continuant, -sonorant] → [+continuant] / V__V	
New rule:	Glottis-[+voice] →	Glottis-[+voice] / <peak>__<peak>
	(Lip-[…])	(Lip-[-stop …])
	(Tip-[…])	(Tip-[-stop …])
	(Body-[…])	(Body-[-stop …])

In the rule given by Kennedy (2016: 136), the target class is defined by the articulator-free features [continuant] and [sonorant], where [sonorant] is used to exclude nasals. In the new analysis, the target class is defined by Glottis-[+voice] (voiced consonants). There is no need to use [sonorant] to exclude nasals, because nasals are unspecified for voice and already excluded from the target class. Besides [b d g ʤ], the target class also include [v z ʒ], but the application to [v z ʒ] is vacuously, because [v z ʒ] are already fricatives.

Next, let us consider an aspiration rule in Yup'ik (Kennedy 2016: 129-130), shown in (31). The consonant inventory is from Jacobson (1984), the source of Kennedy (2016), where parentheses indicate 'rare' sounds.

(31) Aspiration of stops in Yup'ik

Consonants:	[p t ʧ k q (kʷ qʷ) f v s z ɬ ɮ x ɣ xʷ ɣʷ χ ʁ (χʷ ʁʷ) j w m n ŋ m̥ n̥ ŋ̊]
Prose:	[p t ʧ k q] are unaspirated before vowels or nasals
Kennedy:	[aspirated stops] → [plain stops] / _ [sonorants]
New rule:	Glottis-[-voice] → Glottis-[-voice, +aspirated] / __#

In Kennedy's analysis, [p t ʧ k q] in Yup'ik are originally aspirated. They become unaspirated when they occur before vowels or nasals. There are two problems with his analysis. First, it uses two articulator-free features, [stop] and [sonorant]. Second, it departs from Jacobson's (2012: 47) description that 'Yup'ik stops are voiceless and (except at the end of a word) unaspirated.' The new rule agrees with Jacobson's view that Yup'ik stops are voiceless and become aspirated at the end of a word, instead of becoming unaspirated elsewhere. As stated, the new rule applies not just to [p t ʧ k q] but to voiceless fricatives and voiceless nasals as well, but that causes no problem. As I suggested earlier, voiceless fricatives are already aspirated. In addition, in [ɬ], the air is 'blown out the sides between the tongue and the back teeth' (Jacobson 2012: 48), and in voiceless nasals, 'the air is being blown out through the nose' (Jacobson 2012: 49). Therefore, without using articulator-free features ([stop] or [sonorant]), the new rule correctly aspirates [p t ʧ k q] but has no phonetic effect on voiceless fricatives and voiceless nasals, as desired.

As a final example, let us consider a palatalization rule in Kongo (Kennedy 2016: 147-148), shown in (28).

(32) A palatalization rule in Kongo

In IPA: [t s z] → [ʧ ʃ ʒ] / __ [i]

Kennedy: [alveolar] → [palatal] / __ [i]

New rule: Tip-[…] → Tip-[+fricative …] / __ Body-[-back, +high]
Body-[-back, +fricative]

Kennedy's (2016: 147) rule changes [alveolar] to [palatal]; there is also an assumption that other features do not change. In the new rule, the notation '…' refers to whatever other features there are that do not change. The traditional feature [alveolar] is interpreted as the use of Tip and any feature under it, or Tip-[…]. In addition, [ʧ ʃ ʒ] are not just 'palatal' but 'alveolar-palatal', which involves two articulators, Tip and Body. Tip-[…] comes from the original consonant. Body-[-back] comes from the vowel [i]. For [t], the feature [+fricative] appears under both Tip and Body in the output [ʧ]. It is worth asking where [+fricative] comes from. It seems to be related to [+high] of [i], but exactly how [+high] is related to [+fricative] is not completely obvious. The problem is not specific to the present analysis though, but is present in all feature analyses, and I shall leave the answer open.

6. Conclusions

It is a simplification of feature theory if all features can be interpreted as gestures of articulators. However, features that can be performed by two or more articulators, which Halle (1992) calls 'articulator-free' features, pose a new problem. For example, [stop] and [fricative] can each be performed by the articulators Lip, Tip, and Body. In what sense can we still say that Lip-[+stop] (for [p]), Tip-[+stop] (for [t]), and Body-[+stop] (for [k]) share the same feature? An obvious reply is that, if articulator-free features can define sound classes, then the answer is yes. On the other hand, if no sound class requires the use of articulator-free features, then the answer is no.

In this study, I have examined every sound class discussed in the textbook of Kennedy (2016), which includes over fifty rules from eighteen languages. While Kennedy frequently uses articulator-free features to define them, it is found that none of the sound classes requires an articulator-free feature. The result shows that articulator-free features lack empirical justification. It also supports a gestural interpretation of features and simplifies feature theory.

*Acknowledgments: Earlier versions of this paper were presented in 2018 at Peking University, Fudan University, and Northwestern University (MidPhon 23), and in 2019 at Nanjing University. I thank the audiences for their comments.

References:

Archangeli, Diana. 1988. Aspects of underspecification theory. *Phonology* 5.2: 183-207.

Browman, Catherine P. and Louis M. Goldstein. 1986. Towards an articulatory phonology. *Phonology Yearbook* 3: 219-252.

Browman, Catherine P. and Louis M. Goldstein. 1989. Articulatory gestures as phonological units. *Phonology* 6.2: 201-251.

Browman, Catherine P. and Louis M. Goldstein. 1992. Articulatory phonology: An overview. *Phonetica* 49.3-4: 155-180.

Duanmu, San. 2016. *A theory of phonological features*. Oxford: Oxford University Press.

Halle, Morris. 1992. Phonological features. In *Oxford international encyclopedia of linguistics*, ed. William Bright, 207-212. New York and Oxford: Oxford University Press.

Halle, Morris. 1995. Feature geometry and feature spreading. *Linguistic Inquiry* 26:1-46.

IPA. 2018. *The International Phonetic Alphabet* (revised to 2018). https://www.internationalphoneticassociation.org/content/ipa-chart, accessed 6-30-2019.

Jacobson, Steven A. 1984. *Yup'ik Eskimo Dictionary*. Fairbanks, Alaska: Alaska Native Language Center.

Jacobson, Steven A. 2012. *Yup'ik Eskimo Dictionary*. Second edition. Fairbanks, Alaska: Alaska Native Language Center.

Keating, Patricia. 1988. Underspecification in phonetics. *Phonology* 5:275-292.

Kennedy, Robert. 2016. *Phonology: a coursebook*. Cambridge: Cambridge University Press.

Ladefoged, Peter, and Morris Halle. 1988. Some major features of the International Phonetic Alphabet. *Language* 64.3:577-82.

Ladefoged, Peter, and Keith Johnson. 2011. *A course in phonetics*. Sixth edition. Independence, KY: Cengage Learning.

McCarthy, John J. 1991. Semitic gutturals and distinctive feature theory. In *Perspectives on Arabic linguistics III: papers from the Third Annual Symposium on Arabic Linguistics*, ed. Bernard Comrie and Mushira Eid, 63-91. Amsterdam & Philadelphia: John Benjamins.

Mielke, Jeff. 2004-2007. *P-base v1.92*. http://aix1.uottawa.ca/~jmielke/pbase/.

Mielke, Jeff. 2008. *The Emergence of Distinctive Features*. Oxford: Oxford University Press.

Sagey, Elizabeth. 1986. *The representation of features and relations in nonlinear phonology*. Doctoral dissertation, MIT, Cambridge, Mass.

Steriade, Donca. 1987. Redundant values. In *Papers from the 23rd Annual Regional Meeting of the Chicago Linguistic Society, Part 2: Parasession on Autosegmental and Metrical Phonology*, ed. Eric Schiller, Barbara Need, and Anna Bosch, 339-362. Chicago: Chicago Linguistic Society.