Chapter 9

Discussion

Having developed gestural models to account for the behavior of liquid consonants in Spanish (Chapter 5) and Russian (Chapter 8), we will now consider the implications of these models for some broader aspects of liquid phonology. In this chapter, evidence for the gestural acquisition of liquid consonants is examined. Theories of syllabic organization are addressed, and a gestural basis for some cross-linguistic phonotactic phenomena is considered. Some allophonic and historical changes changes involving liquids are described using a gestural model. Representations of laterals and uvular rhotics are discussed. Finally, the problem of capturing classes of liquids will be reconsidered from a gestural perspective, before some problems with the model are outlined, along with suggestions for future research.

9.1 Phonological Acquisition of Liquids

We can account for some trends in phonological development by appealing to a gestural model of liquid structure. Studies of child language acquisition in a variety of languages have reported that:

i. liquids and fricatives are typically acquired later than most consonants
ii. before liquids are mastered, substitution errors are common, and typically involve coronal stops, vowels and glides

This developmental chronology suggests that children first acquire the broad set of gestures involved in liquid production, before refining and differentiating these gestures and establishing the coupling relationships between them.

9.1.1 Acquisition of Liquid Gestures

Two year old children who have largely acquired the stop and vowel contrasts in their native languages often produce liquid consonants as glides. Substitution errors of this type have been reported in English: *lap* [jap], *leg* [jeg], *ready* [wed], *sorry* [sawa] (Fletcher & Garman 1986; Ingram 1989), and Estonian: *raha* [jaha] 'money', *ruttu* [jutu] 'fast' (Vihman 1996), as well as in Turkish, Portuguese, Mandarin, Czech, and Swedish (Yavaş & Topbaş 2004).

If the goals of production of liquids were merely to achieve a certain degree of sonority, as suggested by Wiese (2001a), we might expect children to produce a wide range of segments at this stage of their phonological development. Any number of vocalic or nasal segments, for example, have similarly resonant properties to an English approximant rhotic, and should serve as suitable substitute on prosodic grounds alone. However, acquisition studies reveal a remarkable consistency in the segments which children substitute for liquids in a given language.

In syllable onsets, child learners of American English consistently produce the rhotic as [w], and the lateral as [j] (Dinnsen 1992, Smit 1993). The glide [w] is produced with a labial protrusion and a dorsal approximation; both of these gestures are constituents of the adult phonology rhotic in English (Delattre & Freeman 1968; Gick et al. 2003). The palatal glide substituted for the lateral in the child phonology might represent a first approximation to the more anterior dorsal gesture of the clear /l/ found in onset position in adult English. In other environments, liquids are commonly vocalized by child learners – e.g. *apple* [apo]; *bottle* [babu]; *dinner* [dindʌ] (Fletcher & Garman 1986) – tongue body realizations which closely correspond to the dorsal articulations produced in adult English liquids (Gick et al. 2002; Fig. 1.2).

Different trends are observed amongst children learning Spanish. The Spanish tap /ɾ/ is realized as [ð], [l], and [d] (Anderson & Smith 1987; Goldstein & Iglesias 1996), and coronal trills are first produced as [l] by child learners of Spanish (Stoel 1974; Anderson & Smith, 1987).[1] In contrast to English-speaking children, who seem to acquire tongue body gestures first, these data suggest that Spanish learners might be acquiring coronal articulatory goals before mastering the more global control of the tongue necessary to distinguish the liquids from each other and the stop. Collectively, these data suggest that children are sensitive to the gestural constituency of the liquid consonants used in their language, and the syllable position effects which influence the location and organization of those gestures.

9.1.2 Acquisition of Gestural Coordination

Not only are liquids acquired late, they are also acquired in stages. A developmental trend observed across languages is that a single liquid consonant is usually acquired first, and additional liquid contrasts follow later (Dinnsen 1992; Yavaş & Topbaş 2003). Studdert-Kennedy & Goldstein (2003) have argued that acquisition of more than one liquid is only achieved when the child masters multiple coordination patterns – a hypothesis supported by studies showing late acquisition in Spanish (Anderson & Smith 1987), where three liquids must be differentiated, and Russian (Zharkova 2005), where palatalization contrasts must also be acquired. In Spanish and other languages that contrast tapped and trilled rhotics, pronunciation of liquids also requires differential control of tongue tip stiffness and damping – an additional phonetic dimension which is mastered late amongst native speakers, and never acquired by some second language learners of these languages.

I propose that the pattern of phonological development suggested by the data reviewed in Section 9.1.1 is one in which liquid acquisition proceeds in four broad stages, exemplified for the case of Spanish in Figure 9.1.

Building on the model of phonological acquisition proposed by Goldstein & Fowler (2003), and Studdert-Kennedy & Goldstein (2003), we can hypothesize that children (i) first learn to differentiate contrasts between different speech organs (lips/tongue tip/tongue body), before (ii) learning the most salient phonological contrasts involved in the production of a liquid. In the case of Spanish, this contrast is a tongue-

[1] Trills are initially realized as laterals also by child learners of Italian (Bortolini & Leonard 1991) and Portuguese (Yavaş 1988).

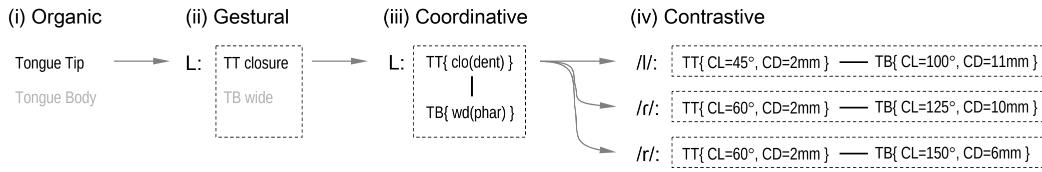

FIGURE 9.1: **Hypothesized stages in the phonological acquisition of liquid consonants**.

tip gesture shared by, but not yet differentiated from coronal obstruents; in English, a tongue body gesture shared by, but not yet differentiated from glides. Children acquire a single liquid when they learn to coordinate tongue tip and tongue body gestures (iii), and finally, acquire multiple liquid segments when they learn how to differentiate the constituent gestures, and control the different coordinate relationships between them.

9.2 Accounting for the Distribution of Liquids

In Chapter 2 it was shown that cross-linguistically, one of the most important properties of the class of liquids is their shared distribution in the syllable. Given that the class is partially characterized by its phonotactic properties, a phonological model of liquid consonants should be able to account for this behavior. Specifically, we are interested in explaining the restricted and asymmetrical distribution of liquids in consonant clusters, and considering whether these ordering relationships might be described in a principled way, consistent with broader theories of syllable structure.

9.2.1 Sonority-Based Accounts of Liquid Phonotactics

Although class-based restrictions on consonantal ordering in onsets and codas have long been observed (Whitney 1865; Jespersen 1904; Saussure 1915), it is still not clear what principles govern these constraints. Accounts of phonotactic organization in the syllable have traditionally appealed to the concept of *sonority*: a scalar property, intrinsic to all segments, which ranks them on a hierarchy and governs their distribution with respect to other segments.[2] In a given string of segments, syllable nuclei should correspond to local peaks in sonority, onsets to sequences of rising sonority, and codas to sequences of falling sonority (Kenstowicz 1994).

[2] Vennemann (1988) proposes that the same distributions are governed by differences in "Universal Consonantal Strength" – the inverse of sonority.

Clements (1990) proposes the minimal sonority hierarchy formulated by Eq. 9.1.

$$obstruent < nasal < liquid < glide < vowel \tag{9.1}$$

A great variety of phonetic and quasi-phonetic correlates to sonority have been proposed, including *Schallfülle* (Sievers 1881), acoustic energy (Heffner 1950; Ladefoged 1971), relative sound pressure intensity (Parker 2008), F1 (Donegan 1985), voiced airflow (Vennemann 1988), and band-limited resonant energy (Clements 2006). Although many of these parameters have been shown to be correlated with groups of sounds which pattern together phonotactically in some languages, none has proven to be robustly associated with the diverse group of segments which function as liquids across languages, nor even with the sets of rhotics which pattern together in the same language (Lindau 1985; Ladefoged & Maddieson 1996).

The liquids produced by the Spanish speakers in the study in Chapter 4, for example, ranged from stop- (Fig. 4.8) and fricative-like segments (Fig. 4.10) to highly resonant approximants (Fig. 4.7). Sonorities measured by any of the phonetic parameters proposed above would differ radically between some of these segments, yet they all exhibit the same phonotactic behavior. Even larger differences in sonority would be observed between the voiced intervocalic stops produced by these speakers – some of which are canonical plosives (Fig. 4.3); others radically lenited approximants (Fig. 4.6) – yet all of these consonants combine with liquids in the same order in Spanish onset clusters, regardless of their relative sonorities.

Because no satisfactory universal definition of sonority has yet been proposed, nor any independent set of parameters by which it might be robustly quantified, Ohala (1992) points out that phonological arguments for the role of sonority hierarchies in determining syllable shape are essentially circular. Liquids are ranked between obstruents and vowels in the sonority hierarchy because clusters of the form #Cl- and #Cr- are more commonly observed across languages than #lC- and #rC- (Chapter 2). When the class of liquids is expanded in more elaborated versions of the hierarchy, rhotics are typically ranked as less sonorous than laterals because codas of the form -rl# are found in Germanic languages, for example, but not -lr# codas (Wiese 2001). The minimum sonority distance principle is evoked to rank trills amongst the least sonorous of liquids, because only laterals and flaps prototypically appear as the second member of complex onsets in Spanish (Baković 1995; Padgett 2003).

Yet if a language uses clusters which violate the SSP, we are forced to modify the hierarchy for that language, revise our conception of the syllable, or simply declare such examples to be exceptional. Although syllable structure in Spanish invariably conforms to the sonority sequencing principles specified by the hierarchy in Eq. 9.1 (Section 3.2), many syllables in Russian do not (Section 6.3.1). Unless we revise the sonority hierarchy for Russian – and also for Polish (*mdły* 'tastless'), French (/mᴏʀdʀ/ 'to bite'), Bella Coola (/pɬtknɬp/ 'bitter cherry tree') and English (*sprints*) – we must appeal to concepts such as extra-syllabicity (Rochoń 2000; Wiese 2001), and additional theoretical apparatus such as syllable appendices (Kiparsky 1979; Vaux 2009).

The circularity of phonological arguments for sonority are also noted by Harris (2006: 1485), who observes:

> "(The sonority hierarchy) is no more than a taxonomic redescription of the patterns it is designed to account for. Its main value is heuristic, aiding the formulation of generalizations about sound sequences that would perhaps otherwise have remained unexpressed or even undiscovered. For the hierarchy to take on explanatory value, it needs to be defined in terms of factors that are independently known to shape the design of phonological systems."

I propose that the relevant set of factors are gestural in nature, and that phonotactic constraints on liquids are not determined by a single parameter, but result from the interaction of a number of factors related to gestural organization and recovery. Although some of these factors vary from language to language, different sonorities are associated with different combinations of gestures which recur in different parts of the syllable, and give rise to the characteristic sonority profiles which are associated with the SSP.

9.2.2 The Gestural Basis of Syllablic Organization

In articulatory phonology, a syllable is modeled as a set of coordinated gestures, bound together through stable coupling relationships (Krakow 1989; Nam et al. in press). Phonotactic properties of segments result from the interaction of three different sets of constraints:

i. general principles of intergestural coordination
ii. language-specific preferences for inter-gestural coordination
iii. constraints related to the recoverability of coordinated gestures

The most fundamental phonotactic properties of the syllable derive from parametric differences in the constituent gestures of segments which act as consonants, and those which act as nuclei. Liquids – like any other type of segment – may function as onsets, codas, or nuclei, depending on the phasing and duration of their constituent gestures with respect to others. Unlike traditional accounts of the syllable, there is no need to specify a hierarchical skeleton of structural positions, nor to stipulate which types of segments or features may fill different slots.

Syllable structure in Hawaiian, for example, is limited to the form (C)V(V) – no codas, complex onsets or syllabic consonants are allowed – so the single liquid /l/ is restricted to the same phasing relationship (0°) and oscillator stiffness ratio (2:1) which defines all consonantal-vocalic coupling relationships. The Hawaiian words *la* 'day', *ma* 'toward' and *ka* 'container' share the same phonotactic structure, governed not by the relative sonorities of their onsets and vowels (which would differ if quantified by any phonetic parameter), but by the stability of the in-phase coupling relationships established between their onset and nucleic gestures.

In contrast to the highly restricted distribution of liquids in Hawaiian syllables, Tashlhiyt Berber allows liquids to appear in all positions in the syllable; like Hawaiian, liquids do not pattern any differently from the other consonants in Berber, as all types of consonant – including voiceless stops – may act as syllable nuclei (Dell & Elmedlaoui 2002). While problematic for sonority-based accounts of syllable structure, the phonotactics of Berber can be reconciled with an articulatory model in which a greater range of gestures may function as nuclei, in which case they would be specified for different durations, and enter into different coupling relationships with their ambisyllabic gestures.

In the word *ts.srw.sak* 'she gave you the impression that ...', the gestures of the nuclear rhotic would be specified for the same duration, and coupled in the same relationship with the onset gestures, as the sibilant and vowel which function as nuclei of the the first and third syllables (Fig. 9.2, right). The rhotic onset in the word *s.ru.sas* 'lay down for him!' would consist of the same gestures, but would be shorter in duration, and coupled in-phase with the high back vowel which is now functioning as the nucleus (Fig. 9.2, left).

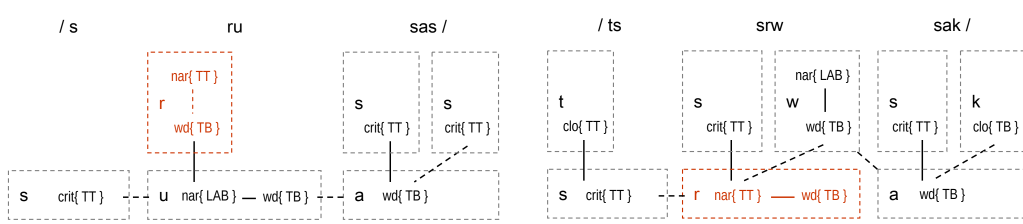

FIGURE 9.2: **Syllabic organization in Tashlhiyt Berber**: liquids – like all other consonants – can appear in syllable nuclei or periphery. The same pair of gestures which serve as a rhotic onset in /s.ru.sas/ (left) can function as a nucleus (/ts.srw.sak/, right) by altering durations and coupling relationships with ambisyllabic gestures.

The phonotactics of liquids in Hawaiian and Berber are maximally different, and reflect two radical types of syllabic organization which resist characterization under frame-and-content theories of syllable stucture governed by scalar sonority hierarchies. The examples above demonstrate that by modeling liquids using a universal set of gestural primitives, we can describe their distributions in all types of syllablic structures in terms of different types coupling relationships, without having to appeal to syllabic templates or to account for issues of sonority.

Given that liquids can appear in all positions in the syllable, the next question to be addressed is why, cross-linguistically, they tend to display the distributional properties identified in Chapter 2 – a capacity to cluster with obstruents, and an ability to function as a nucleus in languages which disallow obstruent nuclei.

9.2.3 The Gestural Basis of Liquid Phonotactics

In both Hawaiian and Berber, onsets are restricted to a single consonant. As syllable complexity increases, two additional, related principles of syllable structure become relevant: competition for articulators, and gestural recoverability. If coordinative stability were the only factor governing gestural organization, all onset gestures would be perfectly synchronous because in-phase coupling is the optimally stable coordinative relationship (Nam & Saltzman 2003). Yet if onset gestures corresponding to different segments were all articulated in parallel, they would not be recoverable by the listener (Mattingly 1981; Browman & Goldstein 2000).

One reason that liquids might be preferred segments in clusters is their multigestural constituency. Clusters of hetero-organic gestures such as -/pt/- and -/pk/- can be overlapped, but are more likely to be reliably recovered by the listener if they are partially displaced in time (Chitoran et al. 2002). Clusters of monolithic homo-organic gestures (e.g. -/pb/-, -/st/-, geminates) *must* be linearized simply in order to be pronounced. Because liquids consist of multiple gestures, they present more options for organization with respect to the other gestures in a cluster, in ways which facilitate both parallel production (Liberman et al. 1967) and recovery by a listener who is cognizant of the potential coupling relationships between gestures in her language.

Two ways in which onsets may be reorganized so as to facilitate gestural recovery are the explicit phasing of gestures with respect to each other, and the spontaneous displacement of gestures in opposite directions around a C-center (Browman & Goldstein 2000). Provided that the resulting phasing does not exceed a critical threshold, both of these processes have the effect of introducing asynchronies which will aid perception by a listener, while still maintaining a stable constellation of gestures in the onset which are collectively in-phase with the nucleus (Chitoran et al. 2002). If an onset contains a consonant and a liquid, there are two ways in which this displacement can be achieved: delaying the obstruent gestures to create the temporal ordering #LC-, or moving the gestures associated with the liquid closer to the nucleus, resulting in onsets of the form #CL-.

When clusters are organized such that obstruents appear closer to the nucleus than liquid or nasals, it would appear to be render the syllable less stable. In Germanic languges, for example, codas of the form -CL# or -CN# are generally not possible because the sonorant is syllabified separately, e.g. English: *bottle* [ˈbʌt.l̩], *butter* [ˈbʌt.r̩], *bottom* [ˈbʌt.m̩] (and see Scheer, 2004, on trapped consonants in Germanic). Even in Slavic languages, which do allow some codas of this form, such combinations have proven historically unstable, e.g. Russian: /sestër/ *'sister-gen.pl'* < /sestrá/; /vʲel/ *'drove-*M.SG.DEF.IMPF' < /vest-l/ (Pugh, 2007; and see discussion in Section 6.3.1). Thus, although both -LC# and -CL# configurations are potential solutions to the problem of gestural displacement to aid recovery in codas, the -LC# ordering would be appear to be optimal in terms of preserving the structural integrity of the syllable. For the same reasons, #CL- appears to represent the optimally-stable recoverable configuration for a complex onset.

Evidence from articulatory studies suggest that the same principle applies to intergestural coordination in complex segments, as well as clusters. Sproat & Fujimura (1993) proposed that timing asymmetries in English coda laterals are the result of the "affinity for the nucleus" shown by the vocalic gesture of the approximant. Browman & Goldstein (1995a) accounted for the lag in tongue tip gestures of nasals and laterals, relative to their corresponding velic and dorsal gestures in English, by proposing that coda organization in English is governed by the principle that "gestures involving wider constrictions precede those with narrower constrictions" – a principle which is consistent with intergestural timing asymmetries observed in coda liquids in Squamish Salish and Mandarin Chinese (Gick et al. 2006), and in coda nasals in English (Byrd et al. 2009). The details of intergestural and cluster timing in Spanish and Russian liquids remain to be investigated; however, the ultrasound data presented in Sections 4.4.2 indicates that dorsal gestures precede tongue tip activity in codas in Spanish.

Bloomfield (1914), Jespersen (1928), Goldsmith (1990) and others have proposed that the phonetic basis of sonority does not lie in the acoustic properties of the speech signal (c.f. Sievers 1881, Ladefoged 1971, Clements 2009, etc.) but corresponds primarily to supralaryngeal aperture. In general, there appears to be an inverse correlation between the constriction degree of a supraglottal gesture and its proximity to the nucleus – a distribution shown in Figure 9.3, where the apertures of the constituent gestures in three English words are plotted over time.

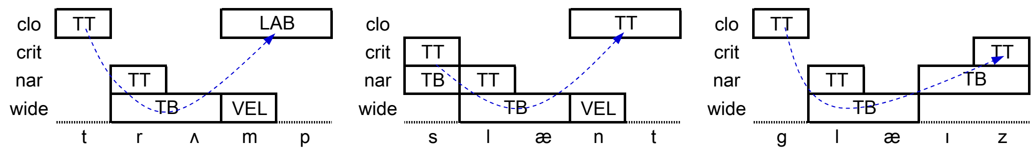

FIGURE 9.3: **Gestural Aperture and Proximity to the Nucleus** – constriction degrees of primary gestures in the English words *trump*, *slant* and *glaze*. Sonority sequencing is an artefact of gestural organization in the syllable.

In summary, if liquids are modeled as coordinative stuctures of consonant-like tongue tip and vowel-like tongue body gestures, then under a coupled-oscillator model of syllable structure, their phonotactic distribution follows from general principles of gestural organization: an interacting set of constraints on coordinative stability, gestural recoverability and language-specific preferences for gestural organization. In both onsets and codas, nasals, liquids and glides tend to distribute closer to the nucleus because they all use an instrinsic gesture (tongue body or velic) of greater aperture than the gestures of the obstruents with which they cluster. A syllable stucture in which these gestures are coupled more closely to the nucleus would appear to be the optimal arrangement for a stable contiguous constellation of gestures which is recoverable by a listener. Under this view, sonority is an artefact of, rather than the governing principle of syllabic organization.

9.3 Liquid Allophony and Change

It was shown in Chapter 2 that, other than their shared phonotactics, the most important property that characterizes liquids is their interchangeability within the class, observed cross-linguistically in rhotic-lateral allophony, alternation, neutralization and other phenomena. In Chapters 5 and 8, some phonological processes specific to Spanish and Russian liquids were examined. In this section, a gestural account of some class-based phenomena involving liquids in other languages will be proposed.

9.3.1 Liquid Allophony in Small Inventories

A gestural model of liquid structure offers some insights into the allophonic variation observed in languages with small consonant inventories. The Papuan language Rotokas, for example, uses only six phonologically constrastive consonants. The three voiced 'stops' are realized as a wide range of consonants which occur in free variation (Firchow & Firchow 1969; Table 9.1). Three different liquids are attested amongst the allophones of the voiced coronal stop, suggesting that the tongue tip gesture is produced in combination with a variety of uncontrolled dorsal postures.

	LABIAL	CORONAL	DORSAL
Unvoiced	[p]	[t] ∼ [s] ∼ [ts]	[k]
Voiced	[b] ∼ [β] ∼ [ʋ] ∼ [m] ∼ [mb]	[d] ∼ [ɾ] ∼ [ɹ] ∼ [n] ∼ [l]	[g] ∼ [ɣ] ∼ [ŋ]

TABLE 9.1: **Consonantal allophony in Rotokas** (Firchow & Firchow 1969; Morén 2007).

Consonantal contrasts in Rotokas appear to be created by coordinating an organically-differentiated constriction (lips/tongue tip/tongue body) with one of two glottal gestures (constricted/open). (Supraglottal) constriction degree is not exploited to create phonological constrast in this system, nor is velic aperture, nor inter-gestural coordination of supraglottal tract variables. Because these other articulatory dimensions are uncontrolled, they can and do modify the salient gestures, resulting in the range of segments which occur as allophones. For example, because nasalization is not contrastive in Rotokas, the velum is phonologically uncontrolled. If it is lowered at the same time that a lip closure gesture is produced, a nasalized allophone of the labial stop will result.

Liquid allophones of voiced coronal consonants are also attested in other languages with small consonant inventories, including Nasioi ([d] ∼ [ɾ] ∼ [l]; Hurd & Hurd, 1966) and Gadsup ([d] ∼ [ɾ]; Frantz, 1976). A liquid allophone of the voiced dorsal stop occurs in Pirahã: [g] ∼ [͡ɺɺ̪] (Everett 1982). Each of these allophones may be considered to result from the unplanned coordination of an additional lingual gesture with the monolithic gesture corresponding to the underlying stop consonant. Dorsal retraction at the same time that the tongue tip closes in the Nasioi /d/, for example, could result in a lateral allophone of the stop, while the coordination of a dental tongue-tip approximation with the dorsal gesture of the stop /g/ could produce the rare flap allophone of Pirahã.

Because these combinations of articulations are cognitively unassociated in these languages, they result in allophonic free variation. The same combinations of gestures have been phonologically harnessed in other languages through the development of additional coupling relationships. One of these relationships – the temporal coordination of a tongue tip and tongue body gesture in a manner which affords spontaneous voicing – is the configuration which corresponds to a phonologically constrastive coronal liquid segment. Some languages only use one such configuration for phonological contrast (Japanese, Korean, Gonja), while languages with more than one liquid consonant have exploited multiple coordinative structures of this type, as we have seen in English, Spanish and Russian.

9.3.2 Phonological Behavior of Post-Vocalic Liquids

In Chapter 2, it was shown that post-vocalic liquids exhibit some common behaviors in many languages: lengthening or altering the preceding vowel, vocalizing, and deleting. Under a gestural model, we can analyze all of these processes as interactions between the tongue body gestures of the nucleus and the liquid.

The compensatory lengthening which accompanies post-vocalic liquid deletion in non-rhotic varieties of English, for example, could result from the reorganization of dorsal gestures in the coda. The gestural score for the word *heart*, as it would be pronounced in a rhotic dialect, is illustrated in Figure 9.4 (left). Because the dorsal targets of English rhotic approximants and low back vowels are very similar (Delattre & Freeman 1968), the nuclear tongue body constriction will not change signifigantly into the coda. If the tongue tip gesture of the rhotic is deleted, delayed or strengthened, such that it blends with, or is masked by the closure gesture of the coda stop, the resulting ensemble of gestures will correspond to a non-rhotic pronounciation, with compensatory lengthening of the nuclear vowel (Figure 9.4 right).

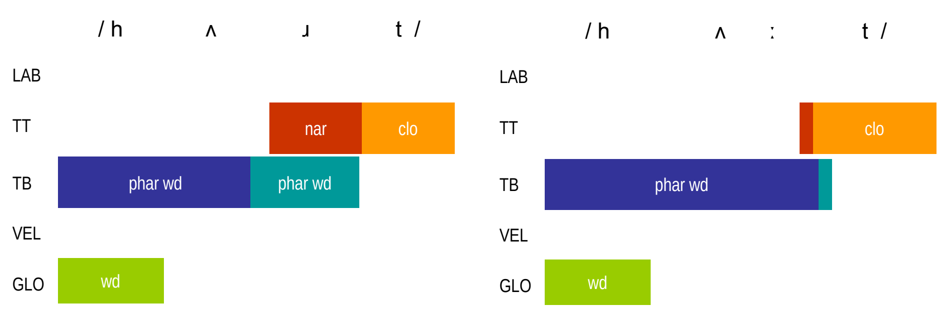

FIGURE 9.4: **Compensatory lengthening resulting from deletion of post-nuclear liquids**: non-rhotic English varieties.

Length-contrastive minimal pairs in Australian English such as *hut* [hɐt]/*heart* [hɐːt] and *huff* [hɐf]/*half* [hɐːf] would appear to be the result of this type of process (Table 2.17). The gestural residue of post-vocalic liquid deletion can be seen even more clearly in words with different types of vowels. When a coda rhotic follows a high or a front non-low vowel in Australian English, the syllable rime is realized as a type of schwa-final diphthong: *tier* [tiːə], *tear (v.)* [tɛːə], *tour* [tuə]. Each of these words concludes with a low back vocalic gesture resembling that of the tongue body gesture which is intrinsic to the English rhotic approximant. Although the tongue tip gesture (and the labial approximation) which was originally coordinated with the coda /ɹ/ has been deleted in non-rhotic dialects, the tongue body gesture remains.

Post-vocalic liquid deletion with compensatory lengthing is a characteristic feature of the Turkic languages (Kavitskaya 2002), and as in Commonwealth Englishes, a relic of the deleted liquid often remains. In Uyghur, for example, affected vowels are lowered when they are lengthened – a process which could result from blending of the tongue body gestures of the nucleus and the deleted coda rhotic: /kör/ [kʰœː] 'look!', /boldi/ [bɔːˈldɪ] 'he became', /ders/ [dæːs] 'lesson', /tar/ [tʰɑː] 'look!' (Johanson & Csató 1998).

9.3.3 Vocalically-Conditioned Liquid Change

It was shown in Chapters 5 and 8 that tongue body constriction location is an essential parameter in the specification and differentiation of liquid consonants. As a result, liquids are prone to change when they occur in some vocalic environments, if the tongue body gestures of the vowels and liquids interact.

An example of this type of vocalically-conditioned change is the rhoticization which occurs in Sphakiá Greek (Section 2.2.7). Trudgill (1989) observes that laterals in this dialect are realized as a retroflex rhotic approximant when they occur before the vowels /u/-/o/-/a/, intervocalically, or after a labial fricative (Table 9.2).

/kaˈli/	[kaˈli]	'good'-f.sg
/kaˈla/	[kaˈɻa]	'good'-n.plu
/ˈlaði/	[ˈlaði]	'oil'
/to ˈlaði/	[tɔˈɻaði]	'the oil'
/luˈtro/	[luˈtro]	'Loutro'
/sto luˈtro/	[stɔɻuˈtro]	'to Loutro'
/aˈvlaki/	[aˈvɻatɕi]	'ditch'

TABLE 9.2: **Rhoticization of clear laterals**: Sphakiá Greek (Trudgill 1989).

Liquid variation in Sphakiá Greek appears to result from the blending of the tongue body gestures of the lateral and the tautosyllabic context vowel. The Greek lateral is a clear /l/ (Trudgill 1989), so we can assume that its dorsal gesture, like that of the Spanish lateral (Chap. 4), has an anterior constriction target location. When produced before a front vowel, the coarticulatory influence of the vowel which is coupled to the dorsal gesture of the lateral – even if the vocalic blending parameters dominate the consonant – will not alter its constriction location significantly, so the liquid is realized as a clear lateral: /kali/ → [kali]. It is noteworthy that very little dorsal displacement due to vocalic coarticulation was observed when the Spanish clear /l/ was produced in a front vowel context (Figs. 4.26 and 4.27).

When the lateral is produced before a back vowel, blending of the lateral and vocalic tongue body gestures appears to cause the dorsum to retract to the more posterior posture used in the English rhotic approximant (Fig. 1.2). The fact that the allophone produced in this environment is perceived as a retroflex approximant suggests that the whole tongue is retracted in the back vowel enviroment – if the tongue tip remained fronted, the ensuing elongation of the tongue would likely produce the percept of an English or Russian-like dark lateral.

The fact that the labial fricative is transparent in this process (/ˈpavlos/ → [ˈpavɻɔs]) is consistent with Gafos' (1999) account of articulatory locality: rhoticization does not occur when a dorsal consonant precedes the lateral because the intervening tongue body gesture would block the contiguity of the vocalic gestures.[3] The labial gesture of the consonant /v/, on the other hand, does not prevent the low vowel of the preceding syllable conditioning the lateral allophony by entering into a local articulatory relationship with the onset lateral (Figure 9.5 right).

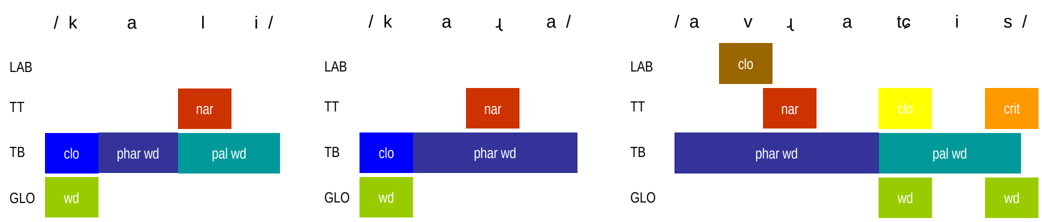

FIGURE 9.5: **An articulatory account of rhoticization of clear laterals in Sphakiá Greek**. Left: clear /l/ coupled to front vowel; Center: rhoticized liquid /ɻ/ coupled to back vowel; Right: articulatory transparency of labial consonant.

9.4 Asymmetries between Liquids

A variety of phenomena were surveyed in Section 2.4 which reveal asymmetries within the class of liquids. Evidence from diachronic stability of clusters, consonant sequencing in clusters, potential for syllabicity, propensity for assimilation and other processes suggests that cross-linguistically, when liquids differ in their behavior, rhotics tend to pattern more closely with vocoids, and laterals with obstruents. The results of the experiments into liquid production described in Chapters 7 and 8 suggest two possible phonetic bases for these asymmetries: (i) differ-

[3] Trudgill (1989) does not give an example of clear lateral allophony after non-labial consonants, but asserts that rhoticization does not occur in this environment.

ences in dorsal aperture and stability, and (ii) differences in tongue tip stiffness, between laterals and rhotics.

Articulatory investigation into dorsal articulation revealed that, of the three liquids, the Spanish trill is characterized as having the greatest stability (Section 4.3.5). The dynamic properties of the tongue body gesture observed in trill production in both Spanish and Russian resemble those of vowels in that they are stable over a prolonged interval – a property which may be essential to maintaining stability in trill production. In the development of Slavic, for example, palatalized rhotics have proven to be more diachronically unstable than non-palatalized rhotics (Carlton 1991), which may be due to the perturbation of the tongue body introduced by the palatalization gesture (Iskarous & Kavitskaya, submitted).

If it is the case that rhotic tongue body gestures are more intrinsically stable over a longer period of time than the tongue body gestures of some types of lateral approximants, this might account for some of the phonological asymmetries observed above: the more 'vocalic' qualities of rhotics could stem from their greater capacity to couple with other gestures in the syllable in a manner which faciliates gestural recovery by the listener.

In the articulatory models of coronal liquids proposed in Sections 5.1 and 8.1, tongue tip damping (and stiffness) was found to be a critical parameter which differentiated the rhotics from the lateral. Although all three liquids in Spanish, for example, share vowel-like dorsal constrictions (TBCD = wide), the lateral was modeled with the same tongue-tip gesture specified for other consonants (damping ratio = 1), while the rhotics were modeled using lightly-damped tongue tip gestures. Because of this difference in gestural constituency, we can consider the lateral – which uses a more rigidly controlled coronal gesture – to be more 'consonantal' than the rhotics. Given that many languages avoid homorganic obstruent-obstruent sequences, presumably because of difficulties in producing or recovering adjacent similar consonantal gestures, this might account for the typological preference for #Cr- over #Cl- clusters, as well as the diachronic instability of #Cl- onsets in Romance (Table 2.22).

While the observations made here are consistent with the articulatory data obtained from these ultrasound studies, they remain speculative. More detailed investigation into patterns of gestural coordination in rhotics and laterals in a greater range of languages will be required in order to examine the possible gestural bases of phonological asymmetries between liquids.

9.5 Uvular Rhotics

It was shown in Chapter 2 that uvular rhotics are problematic for feature-based accounts of liquids, if the canonical form of the rhotic is a fricative, rather than a trill. A sonorant class of liquids can be defined in varieties of French, German, Dutch and Portuguese in which this rhotic is considered to be /ʀ/, but not for varieties in which the canonical form of this phoneme is [ʁ] or [χ], because these segments are [-sonorant].

The fundamental problem is that phonetic relationships between the various allophones of uvular segments are gradient, while the units of representation in feature-based phonological theory are binary. Both sonorant and non-sonorant allophones pattern as rhotics in all of these languages, and the trill /ʀ/ devoices or spirantizes in a wide variety of environments. Uvular phonemes considered to be underlyingly approximant, such as that of oriental Hebrew, are transcribed with the fricative symbol [ʁ] (Laufer 1999): the fact that the IPA does not provide an independent symbol for an uvular approximant suggests that categorical distinctions between trills, fricatives and approximants are not straightforward for consonantal constrictions formed in this region of the mouth.

In an articulatory phonological model, we are better able to model the behavior of uvular consonants because the phonological primitives are neither binary not privative. Tract variable constriction degree targets are categorical, but the linguistic task might be achieved in a variety of ways. The tract variable specification TBCD{crit}, for example, refers to the narrow range of constriction apertures which, given the right aerodynamic conditions in the region of the tract specified by the constriction location, will result in frication. The same constriction, under different conditions, might also produce a trilled or approximant allophone. Despite differences in phonetic realization, the phonological primitives remain the same, and we can define a class of consonants over the group of consonants which share a common set of gestural specifications for constriction degree, constriction location, or both.

9.5.1 Historical Development of Uvular Rhotics

The development of uvular rhotics in languages which previously used coronal trills is not well understood. The development may have been a borrowing in Western European communities which regarded French as a prestige language (Trautman 1880); however, the genesis of uvular rhotics in French rhotics remains to be explained. Regardless of the origins, it is difficult to account for the fact that uvular rhotics coexist with, substitute for, and alternate with coronal rhotics in many languages which use them (Portuguese, Swedish, Hebrew). The innovation can be rapid: (Sankoff et al. 2007) describe a transformation from /r/ to /ʀ/ usage in some Montreál French-speaking communities in the last thirty years.

A gestural model of coronal rhotics can provide some insights into potential mechanisms of change in these langugaes. The articulation of trills in both Spanish (Ch. 4) and Russian (Ch. 7) was shown to involve stable, prolonged tongue body gestures with posterior constriction targets. In the case of Spanish, the dorsal gesture of the trill was the most retracted of all liquids; in both languages, the tongue body raised towards the soft palate during the production of trills in low vowel contexts. If the tongue body gesture in this region became more constricted (through overshoot, for example), frication or trilling of an undercontrolled uvular could result, under the appropriate aerodynamic conditions. With an accompanying lenition and eventual loss of the tongue tip gesture, the transformation to an uvular rhotic would be complete.

9.6 Nasalized Liquids

Nasalized rhotics are found in several Niger-Congo languages including Igbo (/r̃/) and Ghotuo (/ɾ̃/), as well as the Trans-New Guinea language Waffa (/ɾ̃/); nasalized laterals are also attested in Wamey and Umbundu (/l̃/). The segments in these languages – which pattern phonologically with non-nasalized laterals and rhotics (Zec 1995, Newman 2000) – are problematic for the classification of liquids as non-nasal sonorants. In response to this dilemma, Walsh Dickey (1997) proposed the existence of the feature [liquid] to account for minimal pairs such as *ịrị́* 'to creep' / *ịr̃ị́* 'to climb' (Igbo, Dunstan 1969).

No such dilemma exists under an articulary model, where nasalization is controlled by a velic aperture tract variable which can combine with any combination of oral and glottal gestures to create additional phonological contrasts. Assuming that the trill in Igbo, like Russian and Spanish, is produced by the coordination of tongue tip and tongue body gestures, then the nasal trill would involve the coupling of the same two gestures with an additional velic openning gesture. The class of coronal liquids in all of these languages can be characterized in the same way – those segments produced through the coordination of vowel-like dorsal and consonant-like coronal gestures – whether they contain nasalized liquids or not.

9.7 Outstanding Issues

While an articulatory characterization of liquid consonants is capable of accounting for many aspects of their phonology, it also raises some important issues which are yet to be resolved.

9.7.1 Modeling Laterality

The issue of how to deal with all types of lateral segments remains unresolved in the framework of articulatory phonology. While the dark laterals found in Russian, and in English codas can be adequately represented using a purely midsagittal model, it remains to be seen how clear laterals might be properly represented. As the models of Spanish liquids presented in Chapter 5 demonstrate, the relative proximity of the dorsal and tongue tip gestures mean that the tongue is less elongated than in a dark lateral – an difference most obviously revealed in the anomalous trajectories of the higher formants in the speech synthesized from the articulatory model.

More work is required to investigate the phonetic realization of clear laterals in languages such as Spanish and German to determine their goals of production. Further experimentation may reveal additional ways in which the lingual articulation of lateral appoximants differs from that of obstruents, allowing us to better model both clear and dark laterals using the existing set of tract variables. Failing that, it may be the case that laterality must be actively controlled through an additional tract variable.

9.7.2 Uvular Rhotics

More work needs to be done on uvular rhotics. While the analysis presented earlier goes some way towards accounting for their historical origins, and representing them in a way which can be better reconciled with other types of rhotics, they remain a problem for phonological theory. In particular, it remains to be seen exactly how uvular liquids differ phonetically, if at all, from voiced obstruents produced at the same place or articulation. Articulatory investigation of Western Germanic and Slavic languages which contrast uvular fricative and rhotic segments will provide important insights into the phonetic basis of the class of liquids, and will provide an important test case for the model of liquid consonants being developed here.

9.7.3 Modeling Retroflexion

Retroflex consonants present additional challenges to the model of liquid consonants proposed here. Given that all types of retroflex consonant require more global control of lingual articulation than their apical equivalents, it is unclear exactly how retroflex liquids might differ from retroflex obstruents, and how these distinctions might be reconciled with the proposed characterization of liquids as a class. Pilot data is currently being used to examine liquid articulation in Tamil – an ideal language to pursue these issues because of its rich set of liquids and retroflex consonants.