

BRYAN GICK

12.1 Introduction

In a previous volume of this series, Turk (1994: 107) states that 'it is widely assumed that word-initial and word-final consonants are syllable-initial and syllable-final respectively'. However, phonological evidence abounds for complete or partial 'resyllabification' of word-final consonants across word boundaries. Examples of this include such well-known cases as alveolar 'flapping' (Kahn 1976), linking r (McMahon, Foulkes and Tollfree 1994), linking l (Gick forthcoming) and glide formation (Broadbent 1991, Harris 1994), or 'linking' (Whorf 1943). In all of these cases, when it is followed by a vowel-initial word, a final segment adopts characteristics associated either with initial allophones or with word-internal allophones of the variety often referred to as 'ambisyllabic' (Kahn 1976). Acoustic and articulatory studies of English /l/ (Bladon and Al-Bamerni 1976; Sproat and Fujimura 1993) and /r/ (Gick forthcoming) support this view of word-final consonants.

In recent years, researchers have begun using articulatory measures such as gestural timing and magnitude in an attempt to identify the general phonetic correlates of various syllable positions (Krakow 1989; Browman and Goldstein 1992, 1995; Sproat and Fujimura 1993; Wang 1995; see Turk 1994: 113 for earlier citations). The applicability of a gestural approach to the phonological modelling of the syllable would be greatly enhanced if it could be shown that these same correlates can also encompass traditional resyllabification phenomena in English. By reproducing some of the previous results for /l/

under more phonetically constrained conditions, and by additionally observing the behaviour of final offglides in this same environment, it is the goal of the present paper to attempt to identify specifically how, if at all, the spatial and dynamic properties of word-final gestures may be generally influenced by resyllabification.

12.2 Background

As mentioned above, the last decade has seen the emergence of a research programme using articulatory measures as identifying and even defining characteristics of syllable positions. While this effort has met with some success for unambiguously initial and final allophones, there has been little consensus among the few who have investigated the articulatory properties of ambiguously syllabified allophones (Krakow 1989; Sproat and Fujimura 1993; Turk 1994).

For most tokens, Krakow (1989) observes in her two subjects a bimodal pattern of syllabification, where an intervocalic /m/ appears to follow either a distinctly initial or a distinctly final pattern of intergestural timing (as with all of the previous studies cited here, the categories 'initial' and 'final' were based on lexical affiliation). Krakow's study focuses mainly on determining the syllabification of word-medial consonants (such as the /m/ in *seamy*) by comparing them with those in word-initial (*see me*) and word-final (*seem E*) positions. However, without more clearly syllabified final examples (e.g. *seem he*), it is impossible to conclude whether these lexically final allophones are syllable final or ambisyllabic. Turk's (1994) paper is directed even more toward word-internal intervocalic consonants, making it also of only indirect relevance to the present question.

Sproat and Fujimura (1993) are primarily concerned with observing and describing allophonic patterns across boundaries, including word boundaries. Theirs is therefore the only previous study with substantial relevance to the present one. Their results support the conclusion that allophonic variation in American English /l/ is not categorical, but rather that the articulatory properties of final allophones gradiently approach those of initial allophones as the strength of the following boundary decreases. This finding is consistent with the phonological phenomena cited above, suggesting that any effects of partial or complete resyllabification can potentially be elicited by the presence of a following vowel, even across word boundaries.

The following sections will outline what we should expect, based on previous findings, to find as the articulatory correlates of initial and final positions, and how we predict these will vary under conditions of resyllabification. First, a working technical definition of ambisyllabicity will be proposed within a gestural framework.

12.2.1 *Toward a gestural definition of ambisyllabicity*

It has been a particular challenge of the field of laboratory phonology to directly associate phonological concepts such as ambisyllabicity with phonetic properties and testable predictions. The theory of Articulatory Phonology (henceforth AP; Browman and Goldstein 1986, 1989, 1992) provides a useful means of generating such direct connections with the empirical realm. Insofar as syllables have been discussed within this framework (e.g. Krakow 1989; Browman and Goldstein 1992, 1995), it is possible to state a formal definition of ambisyllabicity in gestural terms.

Within one view of AP, many of the properties of a particular allophone are not specified directly, but rather are determined by the phasing of its component gestures to surrounding gestures. Thus, under this view, for example, the spatial displacement of an unambiguously final allophone is the result of a crucial temporal phasing with the preceding vowel gesture, while that of an unambiguously initial allophone results from phasing with the following vowel gesture. Ambisyllabicity, or partial resyllabification, traditionally describes the joint affiliation of an intervocalic consonant with two flanking vocalic peaks (with or without intervening word or other boundaries). A reformulation of ambisyllabicity in terms of AP would therefore state that certain intervocalic gestures are crucially phased to both the preceding and the following vowel gestures.

This gestural analysis of ambisyllabicity makes the specific prediction that, whatever the spatial displacement (or velocity, stiffness, etc.) of a gesture in initial and final position, its ambisyllabic allophone will display an intermediate magnitude between the two. This prediction recalls Turk's (1994: 107-8) statement that '[a]mbisyllabic consonants are predicted to share the phonetic characteristics of both syllable-initial and syllable-final consonants', as well as Sproat and Fujimura's (1993) conclusion that allophonic variation is not categorical, but gradient on the gestural level. It is this hypothesis regarding the gestural characteristics of ambisyllabicity that will be tested in the remainder of this paper.

One additional note on this point: in theory, a word-final segment described here as 'ambisyllabic' could indeed be merely 'bilexical', eliminating the need to include the notion of syllables in the discussion at all. However, this conclusion is inconsistent with the phonological evidence for 'resyllabification' phenomena (e.g. coronal flapping, or others cited in Section 12.1) occurring not only across word boundary, but also within words – both morpheme-internally and across morpheme boundaries.

12.2.2 Gestural syllable position effects

This section will set forth the two articulatory measures that will be used to test for reliable properties of initial and final allophones. Ultimately, these same properties will be observed under conditions of possible resyllabification to test for any degrees of variation between initial and final allophones.

Browman and Goldstein (1992, 1995), based on the previous findings of a number of researchers, have identified two 'gestural syllable position effects', or general effects that seem to apply to the component gestures of any consonant segment occupying a particular syllable position. These are: syllable-position-specific timing between tautosegmental¹ gestures (a property of gestural configuration) and final reduction (a property of gestural scaling).

For this discussion, it will be useful to distinguish between two types of gestures, consonant gestures and vowel gestures. In response to Smith's (1995) treatment of these as phonological categories, Ogden (1995) points out that '[t]he terms "consonant" and "vowel" in Articulatory Phonology need formal definition', going on to say that 'it is the degree of stiffness specified in the task dynamic model which determines consonantality (Browman and Goldstein 1990b: 306)'. Sproat and Fujimura (1993: 304) respond to this relative lack of definition, proposing that 'gestures can be characterised as either intrinsically *consonantal* or intrinsically *vocalic*', where 'consonantal' gestures are defined as those that 'produce an extreme obstruction in the vocal tract' (cf. the phonological feature [consonantal]), and 'vocalic' gestures as those that produce no extreme obstruction, or actively produce an opening, as in the case of the velum-lowering gesture for nasals. This definition of gestural categories will be used in the following sections.

12.2.2.1 Intergestural timing: configurational properties of gestures

Studies of the coordination of component gestures within traditional segments have revealed a patterned timing distinction between initial and final allophones (Krakow 1989; Browman and Goldstein 1992, 1995; Sproat and Fujimura 1993; Wang 1995). In terms of the two categories of gestures described above, the following generalisation can be stated based on Sproat and Fujimura's findings: In initial allophones, consonantal gestures (such as the tongue tip [TT] constriction of /l/) tend to occur earlier than, or simultaneous with, vocalic gestures; in final allophones, this generalisation is roughly reversed. Sproat and Fujimura call this coda effect 'tip delay', in reference to the fact that the TT gesture of /l/ is achieved later than the tongue dorsum (TD) gesture in final allophones.

The results of an attempt to replicate these timing results for /l/, and to further observe them in the glides, will be reported in the Experiment section below. Based on the gestural definition of ambisyllabicity proposed in Section

12.2.1, we should expect ambisyllabic gestures to show a pattern of relative timing that is between those of initial and final allophones.

12.2.2.2 *Final reduction: scaling properties of gestures*

'Final reduction' has also been observed to distinguish initial and final allophones in a wide variety of segments (Giles and Moll 1975; Hardcastle and Barry 1989; Browman and Goldstein 1992, 1995; Byrd 1996; Gick forthcoming). This term refers to the observation that the gestures of syllable-final allophones are smaller in magnitude (scaling) than the corresponding gestures of initial allophones. Essentially this same observation (though with some important distinctions that will not be detailed here) has also been referred to as 'initial strengthening' (see Keating *et al.*, this volume). The term 'reduction' will be adopted arbitrarily for the present purposes without implying that the initial allophone is necessarily the more 'basic' one.

Most of the gestures that have been tested for this property would be classified as consonantal under Sproat and Fujimura's definition. There is a small amount of evidence suggesting that vocalic gestures (e.g. the velum gesture of /m/ or the TD gesture of /l/) do not follow the same patterns of reduction as seen in consonantal gestures (Krakow 1989; Sproat and Fujimura 1993). This question will receive particular attention in the Experiment section.

As suggested above, in AP terms, final reduction may be analysed simply as the difference in scaling between a gesture being phased to a preceding vowel and a following vowel. Thus, we can predict that a word-final consonantal gesture will undergo less reduction when followed by a vowel-initial word than when followed by a consonant-initial word. Insufficient evidence exists upon which to form a solid hypothesis regarding vocalic gestures.

12.2.3 *English liquids and glides*

The articulatory properties of English liquids, particularly /l/, have been relatively well studied. The glides (both initial glides and final offglides), however, have received little attention. If the phonological evidence from 'glide formation' – the apparent 'augmentation' of final offglides when followed by a vowel-initial word or morpheme (Whorf 1943; Broadbent 1991; Harris 1995) – is any indication, investigation of these same properties in glides promises interesting results.

Glides offer the special advantage of being approximant in manner in all positions in English. American English /r/ shares this property, but cannot be included in the present study on the practical grounds that, given the current state of speech measurement technology, it is extremely difficult to collect data on the pharyngeal constriction of /r/ during speech (see Gick, forthcoming, for detailed discussion of this matter). This property of glides allows for

measurement and comparison of small gradient variations in constriction degree, such as those predicted for final reduction, without the physical interference of contact surfaces such as the teeth or palate. It further enables us to categorise the component gestures of glides (the lip constriction and tongue dorsum backing of /w/ and the tongue body raising and fronting of /j/) as 'vocalic' under Sproat and Fujimura's definition. As most previous studies have concentrated on 'consonantal' gestures, such a study of glides provides a useful means for testing these gestural categories.

Certain predictions can be drawn from these properties of English glides. First, according to Sproat and Fujimura's model, the characteristic timing patterns observed in different allophones are due to their status as 'consonantal' or 'vocalic' (with vocalic gestures tending toward, and consonantal gestures away from, the syllable peak). If the component gestures of /w/ are indeed both vocalic, we must revise our hypothesis from Section 2.2.1, and predict that these timing variations will not appear in /w/. (English /j/ is generally considered to be composed of a single gesture and can therefore not be studied for internal timing – though see Keating 1988.) Rather, this view predicts that the /w/ gestures will occur simultaneously in all environments. Second, again assuming glide gestures to be vocalic, their pattern of magnitude reduction is predicted to be parallel to that of the dorsal gesture of /l/ (also a vocalic gesture).

A final note regarding English initial glides and diphthongal offglides: the phonological status of and relationship between the onset glides /w, j/ and diphthongal offglides /ɥ, j/ have been somewhat controversial. The two have been considered distinct by many modern phonologists, with the latter considered by some to be part of the syllable nucleus. As mentioned above, however, diphthongal offglides appear to undergo at least partial resyllabification – a surprising property if they are indeed simply nuclear vowels. More importantly, purely in terms of their gestural componency, these traditionally distinct segments must be considered to be equivalent to pre- and post-vocalic allophones of other segments (e.g. /l, lʲ/). That is, they apparently involve the same gestures (lip constriction and tongue dorsum backing for /w, ɥ/, tongue body raising and fronting for /j, i/). According to the present model, the variations between pre- and postvocalic instantiations of these gestures result from phasing relationships with flanking vowels, not from higher-level (segmental) categorisations.

12.3 Experiment

An experiment was conducted to test the predictions outlined in the previous section. Pre- and postvocalic allophones of /l/, /w/ and /j/ were measured with the goal of identifying characteristic properties of consonantal and vocalic

gestures in various positions, and the effects of across-word-boundary resyllabification on these properties.

12.3.1 Method

12.3.1.1 Subjects

Three native speakers of American English were recorded: JC (female, central New Jersey, early twenties), EM (male, central Maine, early thirties) and MR (male, Southern California, mid twenties). All subjects were students or colleagues from Yale University or Haskins Laboratories. Several potential subjects were interviewed in advance of the experiment to test for vowel quality. Subjects were rejected whose dialects had incomparable vowel qualities within relevant comparison pairs (i.e. if a subject had a low, front [a] in *ha*, he or she was required to have a very similar vowel in *hall*, *how* and *hie*).

12.3.1.2 Stimuli

Stimuli were developed to allow for controlled comparison of ambiguously and unambiguously syllabified word-final allophones of English glides and liquids. Word-initial allophones were also collected. The strategy in constructing stimuli was to create a minimally distinct environment, always using identical words to contain the relevant final glide or liquid (changing only the presence or absence of a following word-initial consonant). /h/ was chosen as the intervening word-initial consonant to establish the following syllable boundary without in any way interfering with the movement of the oral articulators. Otherwise, the relevant glide or liquid was between low vowels. To establish this controlled phonetic environment, it was necessary to use nonsensical word combinations in a uniform carrier phrase – standard practice for experiments of this kind.

Thus, the crucial pair of words used to compare final and ambiguously syllabified allophones of /l/ was *hall hotter* versus *hall otter*; for /w/, *how hotter* versus *how otter*; and for /j/, *hie hotter* versus *hie otter*. Initial allophones were also collected, using *ha lotter*, *ha wadder* and *ha yotter*, respectively (for JC, minimally distinct initial allophones were not collected; initials were taken from tokens *the water* and *how'd water*). To avoid list effects, initial [p] was also used for the first word in the pair (*pa*, *pall*, *pow*, *pie*). Accent on the preceding vowel was effectively maintained by alternating only the first word of each pair within each block of 8 to 12 sentences. In addition, subjects were explicitly instructed to accent the first word of each pair. Within this overall structure, stimuli were presented in random order, in carrier phrases of the form: 'There was a ___ in the house' (for JC and EM), or 'I say ___ again' (for MR). /l/ tokens were collected for subject MR only.

12.3.1.3 Procedure

Subjects were instructed to read stimuli aloud from written lists of 8 to 12 tokens per page in their normal speech and at a comfortable pace.

Data were collected using EMMA (electromagnetic midsagittal articulometer – see Perkell *et al.* 1992), a three-coil transmitter system at Haskins Labs, New Haven, CT. Small receivers were attached to subjects' tongue, lips, mandible, maxilla and nose bridge, with the latter two used for correction of head movement in the midsagittal plane. Voltages induced in the receivers by three fixed electromagnets situated around the subject's head were used to determine location of the receivers in the midsagittal plane. Movement data were sampled at 625Hz for JC and EM, 500Hz for MR. The following receivers and dimensions were used in this experiment: /l/, tongue tip (TT) fronting, tongue dorsum (TD) horizontal; /w/, upper and lower lip (UL, LL) vertical, and TD horizontal; /j/, tongue body (TB) horizontal and vertical (TD was used for MR, because of a bad TB receiver).

12.3.2 Results

All subjects successfully read stimuli with the intended stress pattern and at a comfortable speaking rate. Movement data were analysed using the HADES program (Rubin 1995). Locations of closure achievement were automatically selected from velocity signals (first derivative) calculated from the relevant movement signals, by locating the point at 3 percent short of zero velocity (of the total velocity range for that articulator in that dimension). Movement trajectory maxima and minima were automatically located in movement signals. Between 8 and 12 tokens were originally collected for each condition. Due to minor design changes over the course of the experiment dictated by data-collection time limitations (receivers only stay attached to articulators for a limited time), as well as the occasional unusable token, the final number of repetitions collected and analysed for each subject and condition were:

/w/: JC initial (9), final (9), ambiguous (8); EM initial (12), final (6), ambiguous (12); MR initial (8), final (9), ambiguous (8).

/j/: JC initial (8), final (9), ambiguous (9); EM initial (8), final (8), ambiguous (8); MR initial (10), final (7), ambiguous (9).

/l/: MR initial (8), final (8), ambiguous (8).

Separate one-way analyses of variance (ANOVA) were used to compare mean durations and magnitudes for each subject's productions of each segment across the three syllable positions.

12.3.2.1 /l/: Replication of Sproat and Fujimura (1993)

As noted above, /l/ was collected for only one subject (MR). Figure 12.1 shows results for all three measures of /l/: (a) magnitude (spatial displacement) of the

TT fronting gesture, (b) magnitude of the TD backing gesture and (c) the temporal offset ('tip delay') between the two gestures.

In Figure 12.1(a), mean spatial maxima are shown for the consonantal gesture (TT fronting), with post-hoc tests revealing a significant final reduction effect (leftmost column versus rightmost column, $p < .01$). While there appears to be a tendency toward the predicted intermediate magnitude for the ambiguously syllabified case (centre column), the effect is not significant (initial versus ambiguous, $p < .25$; final versus ambiguous, $p < .12$).

Figure 12.1(b) shows the vocalic gesture (TD backing) to be unaffected by syllable position.

Figure 12.1(c) shows the mean temporal difference between achievement of TT fronting and TD retraction: a positive value indicates that the achievement of the TD gesture occurred earlier than the TT gesture, while a negative value indicates that TT preceded TD. The timing tendencies predicted for initial versus final /l/ based on Sproat and Fujimura's (1993) findings are reflected here, but are again not significant (leftmost versus rightmost column, $p < .06$). The ambiguously syllabified /l/ shows no tendency to stray from the final pattern, again showing a positive lag that is not significantly different from the negative lag of the initial /l/ (centre versus leftmost column, $p < .10$). As Figure 12.4 below will also show, MR exhibited much higher variability in timing than the other two subjects.

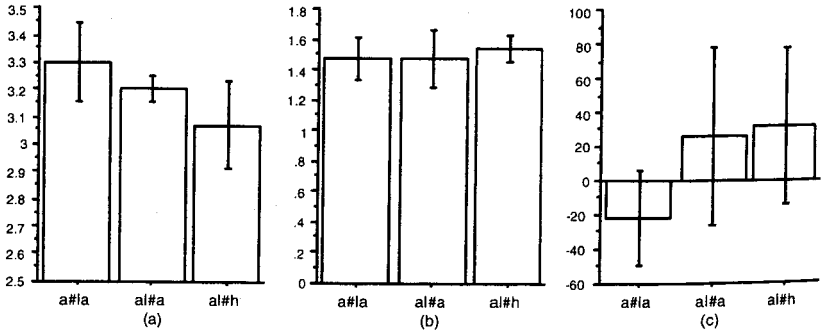


Figure 12.1 Three measures of subject MR's productions of /l/. Graphs compare: (a) mean TT fronting (in cm) for initial, ambiguous and final positions; (b) mean TD backing (in cm); (c) tip delay (in ms). Error bars indicate 95% confidence interval

12.3.2.2 /w/

Figures 12.2 to 12.5 show results for all three subjects' productions of /w/.

In Figure 12.2, despite its being an approximant (vocalic) constriction, final reduction (white columns) is present in the lip-closure gesture for all three subjects, as is the intermediate degree of constriction in ambiguously syllabified tokens (shaded columns). All differences are significant ($p < .05$).

Articulatory correlates of ambisyllabicity in English glides and liquids

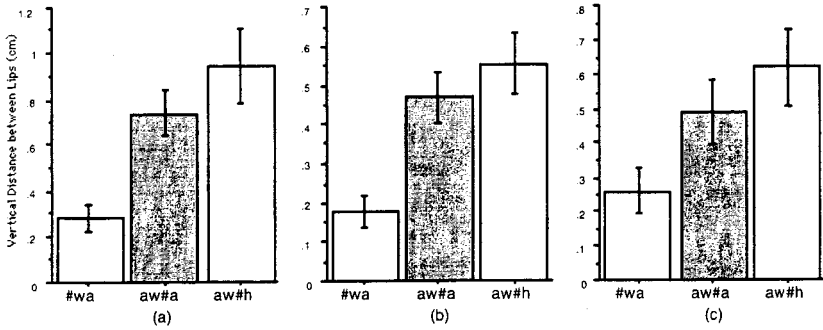


Figure 12.2 Lip aperture in initial, ambiguous and final /w/. Figures (a), (b) and (c) show results for subjects JC, EM and MR, respectively. Columns show mean vertical distance between upper and lower lip receivers (in cm). White bars show final reduction effect; shaded bars show intermediate degree of constriction. Error bars indicate a 95% confidence interval

In contrast to this, Figure 12.3 shows two different patterns: JC's and MR's patterns in (a) and (c) are statistically the same, with both exhibiting significant final reduction but with no significant intermediate magnitudes in ambiguous cases (i.e. leftmost columns are distinct from both right and centre columns, $p < .05$; right and centre columns do not differ significantly for all subjects). For subject EM (b), neither effect is present for TD backing (cf. Figure 12.1(b)).

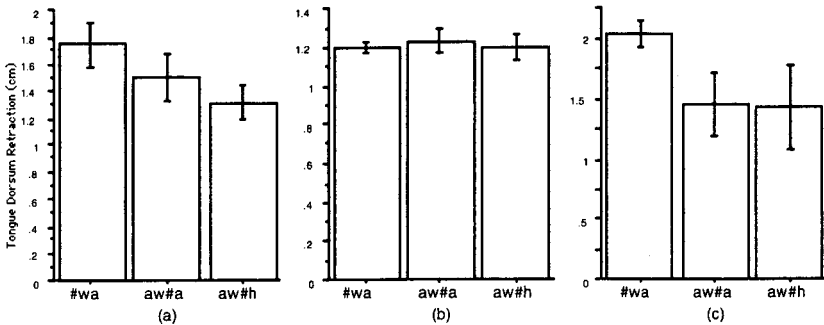


Figure 12.3 TD backing in initial, ambiguous and final /w/. Figures (a), (b) and (c) show results for subjects JC, EM and MR, respectively. Columns show mean horizontal positions of TD receiver (in cm) at maximum retraction. Error bars indicate 95% confidence interval

Figure 12.4 shows a significant effect ($p < .05$) of 'lip delay' distinguishing initial allophones from ambisyllabic and final allophones for all subjects. Contrary to expectations based on Sproat and Fujimura's findings, no intermediate effect is observed for timing (cf. Figure 12.3(a, c)). Figure 12.5 illustrates an example comparison of lip delay from the actual movement data.

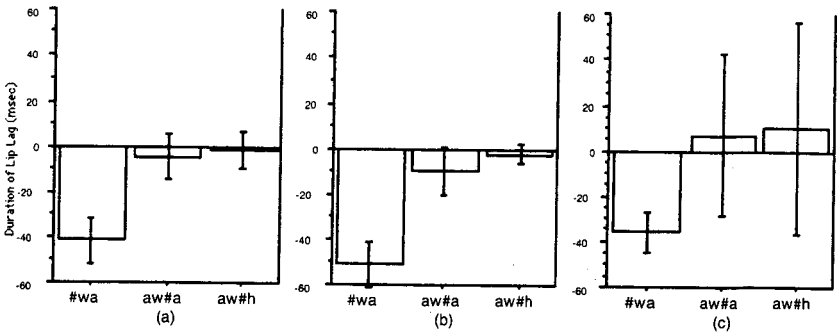


Figure 12.4 'Lip lag' in initial, ambisyllabic and final /w/. Figures (a), (b) and (c) show results for subjects JC, EM and MR, respectively. Columns show mean temporal difference between achievement of lip constriction and TD retraction (in ms). Error bars indicate a 95% confidence interval

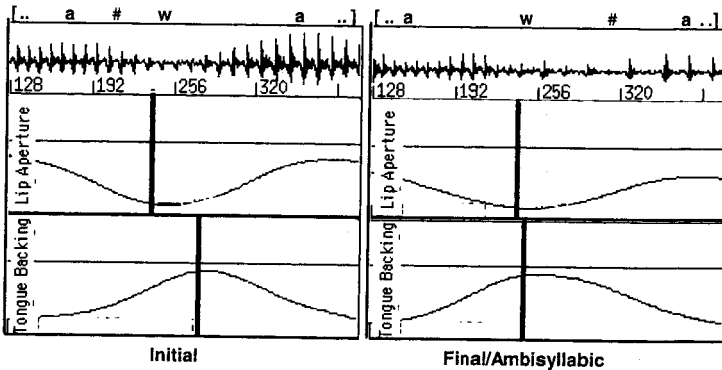


Figure 12.5 Example of intergestural timing in allophones of /w/ for subject EM. Bold vertical lines mark achievement of gestures

12.3.2.3 /j/

Figure 12.6 shows magnitude effects for the TB raising and fronting gesture (TD for subject MR) for all three subjects. The possibility of /j/ containing two distinct component gestures (e.g. tongue body and blade; Keating 1988) was pursued, but without results. It is thus tentatively concluded that /j/ indeed contains only a single gesture. Final reduction effects are significant for all three subjects ($p < .001$), but no intermediate effect can be seen in ambisyllabic cases.

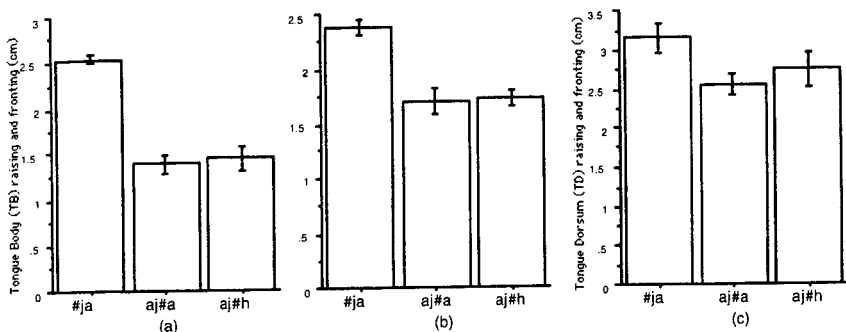


Figure 12.6 Tongue body/dorsum raising and fronting in initial, ambisyllabic and final /j/. Columns show mean Euclidian distances calculated from vertical and horizontal maxima of tongue body (tongue dorsum for MR) receiver (in cm). Error bars indicate 95% confidence interval

12.3.3 Discussion

Two gestures were measured for /l/ and /w/, and one for /j/. For most measures, /w/ and /l/ follow similar patterns in these data, though effects are less pronounced for MR's /l/ than for either the present subjects' productions of /w/, or for the /l/'s reported by Sproat and Fujimura. Some of the predicted gestural evidence for ambisyllabicity was found.

It was predicted in Section 12.2.2 that the present experiment would reveal an intermediate effect in the magnitude of, and timing between, component gestures of American English /l/ and glides. In addition to the (not statistically significant) tendency apparent in the TT gesture of /l/, the shaded bars in Figure 12.2 show evidence of resyllabification in the lip gesture of /w/ (see Gick, forthcoming, for similar results for /r/). The TD gestures of /l/ and /w/, and the TB gesture of /j/ show no evidence for a tendency to resyllabify.

The timing 'tip lag' tendency predicted for /l/ on the basis of Sproat and Fujimura's (1993) findings is also apparent in the present data, though again not significant. Similar (though significant) effects were seen in /w/: contrary to the hypothesis in Section 12.2.3, the gestures of /w/ were not found to be simultaneous. Rather, they follow a 'lip lag' pattern falling within the ranges cited for /l/ by Sproat and Fujimura (1993: 299). Not present in any of the timing effects, however, was the predicted intermediate effect in ambiguously syllabified allophones. It is unlikely that this is due to lack of resyllabification across the word boundary, as both /l/ and /w/ showed the effects of resyllabification in their magnitudes (though in only one gesture each).

12.3.3.1 C-gestures and V-gestures

One point in need of some discussion, and perhaps re-evaluation, regards Sproat and Fujimura's definition of the two categories of gestures,

'consonantal' and 'vocalic'. On the basis of their definition, it was hypothesised in Section 12.2.3 that both gestures of /w/ (because of their relatively open constriction degree) would follow typically vocalic patterns. However, while an analogy can easily be argued for between the TD gestures of /l, w/ and the TB gesture of /j/, the lip gesture of /w/, on the contrary, appears to follow closely all of the patterns predicted for consonantal gestures (final reduction, intermediate magnitude under resyllabification, and tendency away from peak vowel). This interpretation of /w/, while not the predicted one, is consistent with a number of previous findings from the phonological and perception literatures.

Anderson (1976) cites cross-linguistic evidence that, in some languages, the 'primary' articulation of labiovelars, including /w/, is the labial, while in other languages it seems to be the velar. In a recent perception study of American English glides, Lisker (1995) concludes that the primary articulation of /w/ in that dialect is indeed the lip gesture. These cases do not, however, clearly equate 'primary' with 'consonantal' articulations. Such evidence may be provided by onset cluster phonotactics.

Homorganic consonant clusters are generally banned in English onsets (Clements and Keyser 1983: 41; Harris 1994: 57, etc.). While the clusters in *twin*, *dwarf*, *quick* and *guava* present no conflict, no English words may begin with *pw-, *bw-, *fw- or *vw-. Compare this with the corresponding pattern for /l/: *pl-*, *bl-*, *fl-*, *kl-*, *gl-*, but *tl-, *dl-. Thus, the lip gesture of /w/ appears not only to be 'primary', but also 'consonantal', specifically conflicting with other labial (but not velar) consonants – and following a phonotactic pattern parallel to that of the coronal 'consonant' gesture of /l/.

Our experimental results, in addition to the above phonological and perception evidence, thus support the analysis of the lip gesture of /w/ as a 'consonantal' gesture. If this is true, however, then the previous definition of these categories (by constriction degree) must be amended. To eliminate this conflict, I propose the terms 'C-gesture' and 'V-gesture', designating these two gestural types as language-specific, phonologically specified categories (cf. Smith's 1995, need for specified 'consonant' and 'vowel' gestures). This analysis is consistent with Anderson's (1976) observation that the same gesture may be categorised differently in different languages or dialects.

12.3.3.2 A word on V-gestures

Under the hypotheses of the present study, the properties defining a C-gesture have been laid out: (1) final reduction, (2) intermediate magnitude under resyllabification and (3) tendency away from peak vowel. According to this framework, the TT and lip gestures of /l/ and /w/, respectively, are C-gestures, leaving the TD gestures of /w/ and /l/ and the TB gesture of /j/ as V-gestures. This, however may ultimately turn out to be an oversimplification: while there

is no evidence for (2) or (3) in any of the supposed V-gestures, the final reduction effect (1) does appear in the V-gestures of both glides (except for EM's /w/). This could simply mean that final reduction is a freely varying feature of V-gestures, or it may indicate a third class of 'glide' gestures. More data will be required to differentiate between these possibilities.

A related issue regarding the glides is the fact that, in the present model, /w/ involves a C-gesture and /j/ does not. We should expect this difference in gestural composition between /w/ and /j/ to be reflected in the status of these segments in other realms (phonology, perception, development, etc.). Such a difference may be found in the phonologically based stance of numerous researchers (Clements and Keyser 1983; Davis and Hammond 1995, etc.) that /j/ – as an onglide, an offglide, or both – should be considered part of the phonological nucleus, even in cases where a corresponding /w/ would be part of the onset. Further support for this distinct categorisation of /j/ can be found in the phonological development literature, where Barlow (1995) shows that for many children, while /w/, /r/ and /l/ pattern with other consonants in onset clusters, /j/ is treated more like a vowel. Such asymmetries, not easily accounted for by previous segmental theories, are consistent with the present results.

12.4 Conclusion

This paper has proposed an analysis of syllable-based allophony in which traditional segments are composed of two types of gestures, C-gestures and V-gestures, which are phased with respect to each other, in fixed, language-particular patterns. Gestural resyllabification effects were observed, providing evidence that a gesture can be simultaneously phased to flanking syllable peaks (ambisyllabicity). The present data thus lend further support to gesture-based theories of the syllable, such as those previously proposed by Krakow (1989), Browman and Goldstein (1992, 1995), Sproat and Fujimura (1993) and others. This model of syllable structure has here and previously been shown to account for a wide variety of phonological phenomena.

Properties distinguishing initial from final allophones of /l/ and glides were found, as expected from previous results, to be twofold: compared to initials, final allophones show a reduction in magnitude of the C-gesture and a relative temporal 'lag' of the C-gesture with respect to the V-gesture. Ambisyllabic allophones (here, lexically final gestures phased across a word boundary) show a sensitivity to following context, but this is only manifest in gestural magnitude, and only in one type of gesture: the C-gesture. It is concluded that it is precisely this effect that underlies the phonetic distinction between syllable-final and ambisyllabic allophones, and that reference to gestures is necessary to account for these traditionally segment-level patterns.

Notes

The author wishes to thank Louis Goldstein and Doug Whalen for continued discussion and support, Peter Ladefoged, Diamandis Gafos, Steve Anderson, two anonymous reviewers and the volume editors for many helpful comments, and Masanobu Kumada, Dani Byrd and Vince Gracco for assistance at various points in the data collection and analysis. Work supported by NIH grants DC-02717 and HD-01994 to Haskins Labs and an NSF Graduate Fellowship to the author.

- 1 Although AP treats segments and other suprasegmental phonological categories (including syllables) as epiphenomenal, the particularly 'tight' gestural relationships within traditional segments have been recognised (Byrd 1996; Gick 1999). The present paper assumes that these gestural relationships themselves determine the higher-level categories. Whether this truly invalidates the categories as independent units, however, is controversial, and beyond the scope of the present paper. In any case, traditional terminology will be used throughout for ease of discussion.