

Cross-linguistic patterns of vowel intrusion*

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Abstract

Vowel sounds may be inserted into a word by two mechanisms: insertion of a vocalic articulatory gesture (epenthesis), or retiming of existing gestures to produce a vowel-like transition between consonants (intrusion). I argue that epenthetic vowels are phonological units but intrusive vowels are not. A representation using abstract gestures as well as segments can capture facts about the typology of vowel intrusion.

1 Introduction

This paper examines the differences between two kinds of ‘inserted’ vowels. One kind is epenthetic vowels, which are phonological segments inserted in order to repair illicit structures. The other kind, which I will call ‘intrusive vowels’, are actually phonetic transitions between consonants.¹ A distinction like this has been argued for before (e.g., Levin 1987, Warner et al. 2001:416, Harms 1976), but there is disagreement about the precise nature of the distinction. This paper makes the following contributions to the debate: (a) new diagnostics for intrusive vowels based on a typological survey; (b) evidence that intrusive vowels are not phonological units and do not form syllable nuclei at any level of representation; and (c) a characterisation of vowel intrusion in terms of abstract articulatory gestures.²

Since the advent of Articulatory Phonology (Browman & Goldstein 1986 et seq.), it has been proposed that perceived vowel sounds can arise from at least two arrangements of articulatory gestures. The default case is that each perceived vowel

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¹Throughout the paper, intrusive vowels will be underlined and epenthetic vowels will not.

²A note on terminology: the term *intrusive vowel* has also been used by Harms (1976) and Engstrand (1987:105). Some of these vowels have also been called *exrescent*, *parasitic*, *svarabhakti*, *transitional*, *weightless* or other terms listed in Levin (1987). I have chosen to call them intrusive because they are similar to intrusive stops (Clements 1987), like the [t] in *mince* [mints], in being an effect of articulatory timing (Ohala 1997).

sound is uniquely associated with a group of gestures (most importantly, a tongue body gesture). However, Steriade (1990) and Browman & Goldstein (1992) have argued that a vocalic sound can also be produced between consonants through a retiming of existing articulatory gestures, without addition of a vowel articulation. When two consonant gestures are produced with a low degree of overlap, there is an acoustic release between them, which may be interpreted by the listener as a vowel. If the tongue body is in a fairly neutral position, or this period is short in duration, the perceived vowel will sound like a schwa. The consonant cluster may also be overlapped by a vocalic gesture associated with a preceding or following vowel segment. If this vowel articulation overlaps the period of release, the vowel's quality can be heard briefly between the consonants, making the release sound like a copy vowel. Diagram (1) shows roughly the proposed gestural representation of a word (Scots Gaelic [tarav], 'bull') with an intrusive copy vowel. Each curve represents the dynamic cycle of one oral gesture. The intrusive vowel is underlined.

(1) A gestural representation of vowel intrusion: Scots Gaelic [tarav] 'bull'

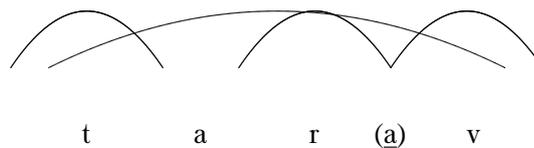


Table 1 lists some vowels that can plausibly be analysed as having such a gestural structure. Phonologists have already proposed gestural analyses of some of these cases, including Hocank (Steriade 1990; Clements 1991), German (Jannedy 1994), Scots Gaelic (Bosch 1995; Hind 1996), Moroccan Colloquial Arabic and Sierra Popoluca (Gafos 2002) and Spanish (Bradley 2002). The widespread interest in a gestural representation for these vowels comes largely from the fact that it can capture facts about the phonetic nature of the vowels.

It is not agreed, however, what the phonological implications of the gestural analysis are, and in particular whether vowel sounds formed this way count as syllable nuclei. According to Steriade (1990), moving a consonant gesture over a vowel gesture as in (1) 'automatically turns a monosyllable into a disyllable.' Yet Bosch (1995:2) suggests that in Scots Gaelic, "the syllable formed by the [intrusive] vowel is... an extension of the original syllable, as opposed to a second, new syllable position, thus pointing to the need for a gradient rather than discrete understanding of the syllable as constituent." I will argue for a third position: syllables are discrete units, but gestural retiming is not in itself sufficient to create a new syllable, and intrusive vowels are not syllable nuclei. Ordinary epenthetic vowels, however, are syllable nuclei. I will show that non-syllabic behavior is found most often in precisely the set of vowels that have characteristics consistent with a gestural analysis.

To capture this connection between vowels' non-syllabicity and their gestural nature, I will argue that it is necessary for phonological representations to include

segments and syllables as well as gestures. The use of segments and syllables is a departure from classic Articulatory Phonology, which does not contain such units (although they are standard in most phonological frameworks). However, an adequate account of the phonological differences between epenthetic and intrusive vowels seems to require explicit reference to syllables. In this respect, the theory presented here is similar to that of Zsiga (1997), who argues that representations contain both autosegmental features and articulatory gestures, and that different processes refer to one or the other. Gestural representations are superior to traditional representations for modeling vowel intrusion, but insertion of gestures and reference to syllables is necessary to model epenthesis (the problems of modelling epenthesis in Articulatory Phonology are also discussed by Warner et al. 2001:415).

2 Intrusive and epenthetic vowels: an overview

2.1 Diagnostics

When a vowel of predictable quality occurs predictably in a given environment, it is analysed as being absent from the underlying representation. For the moment, I will refer to all such vowels as ‘inserted vowels’.

Inserted vowels do not all have the same phonetic or phonological characteristics. Some inserted vowels sound exactly like lexical vowels within the same language, while other inserted vowels may be shorter, longer, or different in quality from lexical vowels. Some inserted vowels affect phonological patterns like stress assignment, while others do not. Some inserted vowels appear to have the function of repairing illicit syllable structures; others do not. Sometimes native speakers are aware of the inserted vowels; in other cases they are not.

One way of modelling the difference between types of inserted vowels is to propose that they are inserted at different stages in the phonological derivation. Vowels inserted late will not be visible to phonological rules that have already applied. In addition, rules that apply late are more phonetic, and hence late vowel insertion is more likely to produce vowels that are acoustically weak. It is common to refer to late-inserted vowels as excrescent (Levin 1987).

However, there are reasons to reexamine the definition of excrescence. One is the need to explain why phonological invisibility, a characteristic of late-inserted vowels, tends to correlate with a group of other properties. In Table 1, I have collected examples of vowels that occur in CC clusters and behave as phonologically invisible, or which are described as excrescent or transitional (the group referred to here as intrusive). Certain characteristics of their distribution and quality are strikingly recurrent across languages. These characteristics are listed in (2).

Armenian	/t ^v husdr/	→	t ^h usd ^ə r	‘daughter’
Breton	/arxant/	→	araxānt	‘silver’
Bulgarian	/garbav/	→	garəbav	‘hunchbacked’
Chamicuro	/tuʔlu/	→	tuʔulu	‘chest’
Dutch	/kalm/	→	kaləm	‘quiet’
English (var. dialects)	/arm/	→	arəm	‘arm’
Finnish	/kalvo/	→	kalavo	‘transparency’
German (S. Hamburg)	/bɔratən/	→	bəɔratən	‘to fry’
Hausa	/kurkutu/	→	k ^w ur ^u k ^w u:tu	‘small drum’
Hocank	I. /sni/	→	sīnī	‘cold’
	II. /ho:tʃāk-ra/	→	ho:tʃəg ^ə rə	‘the Hocank’
Hua	/okrumaʔ/	→	ok ^u rumaʔ	‘sky’
Imdlawn Tashlhiyt Berber	/smd-x/	→	smdəx	‘I added’
Irish (West Muskerry)	/gʲiʲaun/	→	giʲiʲaun	‘valley’
Kekchi	/paʔt/	→	paʔat	‘twins’
Kera	/kɛtɔɛŋ/	→	kɛt ^ə ɔɛŋ	‘chatted’
Lakhota	/gla/	→	g ^a la	no gloss
Mamaide	/mih-takʔu/	→	mihitakʔu	‘it is cloudy’
Mokilese	/pwedla/	→	pwedila	‘lucky’
Mono	/gàfrū/	→	gàfūrū	‘mortar’
Moroccan Colloquial Arabic	/katb/	→	kat ^ə b	‘write (act. part.)’
Piro	/ʃjo/	→	ʃ ⁱ jo	‘bat’
Popoluca	/itʔa/	→	it ^a ʔa	‘your father’
Saami	/skuol:fi:/	→	skuol:əfi:	‘owl’
Sanskrit	/darʃata/	→	darəʃata	no gloss
Scots Gaelic	/ʃaɫk/	→	ʃaɫək	‘hunting’
Sierra Popoluca	/miɲpa/	→	miɲ ^ə pa	‘he comes’
Spanish (Chilean)	/kronika/	→	k ^ə ronika	‘chronicle’
Tiberian Hebrew	/ʃalaħ-t/	→	ʃalaħat	‘you (fs) sent’
Upper Chehalis	/q ^w óɫweʔ/	→	q ^w óɫəweʔ	‘maple’

Sources: Armenian: Vaux (2003); Breton: Jackson (1967); Bulgarian: Jetchev (1995); Chamicuro (Arawakan, Peru): Parker (1994); Dutch: Booij (1995:127); English: Wright (1905:206); Finnish: Harrikari (1999); German: Jannedy (1994); Hausa: Hodge (1947:12); Hocank (aka Winnebago): Miner (1979, 1992); Hua (Papuan, New Guinea) Haiman (1980); Imdlawn Tashlhiyt Berber: Dell & Elmedlaoui (1996); Irish: Ó Cuív (1968:106); Kekchi (Mayan, Guatamala): Campbell (1974); Kera (Chadic, Chad): Pearce (2004:15) and Pearce, p.c.; Lakhota: Albright (1999); Mamaidé (Nambiquára, Brazil): Eberhard (1995); Mokilese: Harrison (1976); Mono (Niger-Congo; Congo): Olson (2003); Moroccan Colloquial Arabic: Heath (1987); Piro: Matteson & Pike (1958); Popoluca (San Juan Atzingo Puebla dialect): Krumholz et al. (1995:282); Saami: Bye (2001); Sanskrit: Allen (1953); Scots Gaelic: Borgström (1940); Sierra Popoluca: Elson (1947); Spanish: Garcia-Bellido (1999); Tiberian Hebrew: McCarthy (1979); Upper Chehalis: Kinkade (1963–4).

Table 1: Examples of vowel intrusion

- (2) Properties of phonologically invisible inserted vowels (intrusive vowels)
- a. The vowel's quality is either schwa, a copy of a nearby vowel, or influenced by the place of the surrounding consonants.
 - b. If the vowel copies the quality of another vowel over an intervening consonant, that consonant is a sonorant or guttural.
 - c. The vowel generally occurs in heterorganic clusters.
 - d. The vowel is likely to be optional, have a highly variable duration, or disappear at fast speech rates.
 - e. The vowel does not seem to have the function of repairing illicit structures. The consonant clusters in which the vowel occurs may be less marked, in terms of sonority sequencing, than clusters which surface without vowel insertion in the same language.

By contrast, inserted vowels that are visible to other phonological patterns (referred to here as epenthetic) tend to have the characteristics in (3).

- (3) Properties of phonologically visible inserted vowels (epenthetic vowels)
- a. The vowel's quality may be fixed or copied from a neighboring vowel. A fixed quality epenthetic vowel does not have to be schwa.
 - b. If the vowel's quality is copied, there are no restrictions as to which consonants may be copied over.
 - c. The vowel's presence is not dependent on speech rate.
 - d. The vowel repairs a structure that is marked, in the sense of being cross-linguistically rare. The same structure is also likely to be avoided by means of other processes within the same language.

The correlation between these properties is not fully explained simply by saying that some vowels are inserted earlier than others.

A second reason to revisit the established analysis of vowel insertion is that the theoretical device of ordering phonological rules has lost favor with many phonologists in recent years, as an over-powerful mechanism that can produce too many unattested rule interactions. Phonologists working in Optimality Theory (OT) (Prince & Smolensky 1993) need to distinguish the different types of inserted vowels in a way that does not depend on serial derivation. The theory proposed here will be useful for OT phonologists, in that it permits a simple non-serial analysis of some apparently opaque rule interactions.

The evidence for the characteristics in (2) and (3) will be presented in more detail in section 5, but first I will give examples of intrusive and epenthetic vowels in two languages that have both.

2.2 Intrusive and epenthetic copy vowels in Mono

Mono, a Niger-Congo language of Congo, has two types of inserted copy vowels (Olson 2001, 2003). The first type is inserted at the beginning of words that are underlyingly monosyllabic, like those in (4). The evidence that the initial vowel is not underlying is that it is absent when the same root occurs in polysyllabic words. This vowel shows the cluster of properties given for epenthetic vowels in (3). It copies the quality and tone of the vowel to its right, regardless of whether the intervening consonant is a sonorant or obstruent. The vowel's presence is not dependent on speech rate. Cross-linguistically, monomoraic lexical words are often avoided (McCarthy & Prince 1993), so the vowel has the function of repairing a marked structure.

- (4) Mono vowel epenthesis Olson (2003)
- | | | | |
|-------|---|------|---------|
| /ɔ̄/ | → | ɪ̄ɔ̄ | ‘tooth’ |
| /bè/ | → | èbè | ‘liver’ |
| /mà/ | → | àmà | ‘mouth’ |
| /ngú/ | → | úngú | ‘water’ |

The second type of inserted vowel occurs in clusters of an obstruent followed by a liquid, as shown in (5). It too copies the tone and quality of the following vowel. This vowel shows the properties of intrusive vowels listed in (2): it copies over a sonorant, and is optionally absent in casual speech.

- (5) Mono vowel intrusion Olson (2003)
- | | | | |
|--------------|---|-------------------------|------------|
| /gàfrū/ | → | gàfūrū ~ gàfrū | ‘mortar’ |
| /plézū/ | → | pélézū ~ plézū | ‘bat’ |
| /jābrù/ | → | jābūrù ~ jābrù | ‘goat’ |
| /dókólóngbā/ | → | dókólóngbā ~ dókólóngbā | ‘scorpion’ |

An interesting feature of the intrusive vowel is that it does not count in determining whether a word reaches the two-syllable minimum. Even if an underlyingly monosyllabic root is pronounced with an intrusive copy vowel, an epenthetic copy vowel must also be added, as shown in (6). The intrusive vowel evidently does not count as a syllable.

- (6) Mono intrusion & epenthesis Olson (2003)
- | | | | |
|--------|---|----------------|---------|
| /gré/ | → | égéré ~ égré | ‘big’ |
| /kplú/ | → | úkpúlú ~ úkplú | ‘heap’ |
| /prō/ | → | ōpōrō ~ ōprō | ‘egg’ |
| /krō/ | → | ōkrōrō ~ ōkrō | ‘skull’ |

In Mono, then, the type of inserted vowel that is speech-rate dependent and copies over only sonorants does not count as a syllable nucleus for minimal word size requirements, while the type of inserted vowel that is not speech-rate dependent and copies over any consonant does count. Another example of this correlation occurs in Kekchi, discussed below.

2.3 Intrusive and epenthetic copy vowels in Kekchi

In the Cobán dialect of Kekchi, a Mayan language of Guatemala, a copy vowel that I analyse as intrusive appears within final clusters of a glottal stop followed by any consonant, as in (7) (all data in this section are from Campbell 1974). These clusters may be tautomorphemic, or else result from attachment of the intransitive infinitive suffix $[-k]$ to a $[ʔ]$ -final root. This conditioning environment matches that described in (2): the copy vowel occurs after a guttural and copies over that guttural.

- (7) Kekchi vowel intrusion Campbell (1974)
- | | |
|-------------------|-------------------|
| poʔ <u>o</u> t | ‘huipil (blouse)’ |
| kaqtuʔ <u>u</u> j | ‘red ant’ |
| iʃiʔ <u>i</u> k | ‘(finger)nail’ |
| seʔ- <u>e</u> k | ‘to laugh’ |
| kwaʔ- <u>a</u> k | ‘to eat’ |

Kekchi also inserts copy vowels between C-final roots and certain C-initial verbal suffixes, as below. These vowels display the characteristics of epenthetic vowels listed in (3a,b). They copy the quality of the vowel to the left, regardless of the identity of the intervening consonant. CC clusters are avoided in many languages, so the epenthesis removes a marked structure.

- (8) Kekchi vowel epenthesis Campbell (1974)
- | | |
|---------------|------------------|
| ninkwiq'-i-b' | ‘I bend it’ |
| ninhup-u-b' | ‘I turn it over’ |
| k'ox-o-b'a:nk | ‘to begin’ |
| atʃ'-a-b'a:nk | ‘to loosen’ |

These two types of copy vowels are treated differently in a language game called Jerigonza. The game consists of inserting after every vowel a sequence $[pV]$, where V is a copy of the preceding vowel. For example, the name of the game $[xerigonza]$ is rendered as $[xepiripigoponsapa]$.

Epenthetic vowels have two possible outputs in the game. Either $[pV]$ is inserted after the epenthetic vowel, or the epenthetic vowel deletes. Campbell suggests that the optional omission of the epenthetic vowel indicates that the game can access the underlying representation, in which these vowels are absent.

- (9) kwiq-i-b'ank ‘to bend it’ → kwipiqipib'apank ~ kwipiqb'apank

Intrusive vowels also have two possible outcomes. As with epenthetic vowels, it is possible to insert $[pV]$ after each vocalic period, suggesting that these $[VʔV]$ sequences are optionally treated as disyllabic. But it is also possible to insert a $[pV]$ only after the intrusive vowel, leaving the other vowel alone.

- (10) tʃaʔax ‘difficult’ → tʃapaʔapax ~ tʃaʔapax

This special treatment happens only with intrusive vowels, not with underlying $/N_i?V_i/$ sequences. For example, $/tʃaʔ-aq/$ ‘say.FUT’ is realised in the game as $[tʃapaʔapaq]$, not as $*[tʃaʔapaq]$.

The treatment of the intrusive vowel in Jerigonza poses an interesting problem. At first glance, it seems like it is the intrusive vowel that is phonologically visible while the underlying vowel is not, since the game inserts $[pV]$ after the intrusive vowel only. Another way of seeing the pattern, however, is to say that the game treats the entire $CV?VC$ sequence as a single syllable. This is essentially the solution offered by Campbell: ‘The very fact that jerigonza can skip over the first vowel demonstrates that the complex vocalic nucleus ($V_1?V_1$) is perceived in some sense as a single unit.’ A gestural analysis like that in (1) helps us to formalise the sense in which the vowels are a single unit: they are two time-periods of a single vowel gesture. In the game, each vowel gesture is doubled once. It would appear that the game preserves the original timing relation between the gestures associated with the vowel and $[ʔ]$. So, when the doubled vowel is inserted, it follows the ‘intrusive’ portion of the original vowel gesture.

Incidentally, rule-ordering would not help describe this interaction. If vowel intrusion preceded Jerigonza, this would result in $[tʃapaʔapax]$. If Jerigonza preceded vowel intrusion, this would result in $[tʃapaʔax]$. No ordering of vowel intrusion and Jerigonza can produce the outcome $[tʃaʔapax]$.

3 Non-syllabicity

3.1 Syllables as mental objects

Before presenting more evidence that intrusive vowels are not syllable nuclei, it is important to clarify that the term ‘syllable’ is not being used to describe an acoustic object. A syllable is an abstract phonological unit that is visible to phonological patterns such as stress assignment, minimal word requirements, allomorph selection, etc. But there is no cross-linguistically valid acoustic characterisation of what constitutes a syllable.

One illustration of the non-acoustic nature of the syllable is the fact that speakers of different languages may interpret the same acoustic signal as containing different numbers of syllables. For example, Harms (1976:74), who gives an informal gestural account of intrusive schwa in Finnish, reports that Finnish and English speakers interpret acoustically similar schwas differently.

$[mɛlɔkein]$ (*melkein*) ‘almost’ has essentially the same vowel qualities ($[ɛ, ə, eɪ]$) and relative durations as the English verb *delegate*— $[dɛləgeɪt]$. From a descriptive phonetic point of view, the Finnish [intrusive] schwa and the English reduced-vowel schwa represent very nearly identical classes of vowel sounds; i.e., they vary over a wide central area, with their range of variation conditioned by the preceding and following segments. But here the similarity ends. The schwa

in the above Finnish forms is purely transitional in nature. Speakers perceive these forms as containing only two syllables, not three.

To the extent that perception is based on a listener's native language, a listener may misperceive the number of syllables in a word from another language. According to Wiik (1965:28), some Finnish learners of English have difficulty in perceiving the difference between words like *scalping* ['skælpɪŋ] and *scalloping* ['skæləpɪŋ], because they hear these words as containing the same segments. They perceive the English schwa not as a syllable nucleus, but as an optional phonetic transition between [l] and [p], supporting the contention of Ohala (1990b:331) that in some cases 'syllabicity is a perceptual object, i.e., created in the mind of the listener.'

I suggest that a purely perceptual object has limited relevance to phonology, and that the perceptual or 'phonetic' syllable (Grammont 1933) needs to be strictly distinguished from the phonological syllable.³ An English speaker's perception of the syllable count of a Finnish word (or vice versa) can tell little about how that word should pattern in Finnish phonology. What matters for this purpose is how the native speaker mentally represents the word. For Finnish, Harms's and Wiik's claims that native speakers consider intrusive vowels non-syllabic match with the vowels' phonological patterning. Harrikari (1999:8) observes that a word with two underlying vowels and one intrusive vowel, like [ohora] 'barley,' cannot take a partitive plural allomorph that selects for trisyllabic bases (in the dialect she treats, the intrusive vowel is a copy vowel rather than a schwa).⁴

If syllabicity is a construct of the native speaker's mind, the presence of a syllable cannot be verified through strictly phonetic means, nor by a linguist's ear, contrary to assumptions that crop up frequently in the literature. Evidence for a vowel's syllabicity needs to be based on native speaker intuitions and on phonological patterns that are sensitive to syllable count. Native speaker intuitions regarding intrusive vowels are occasionally reported: for example, Pearce (2004:19) asked speakers of Kera to choose between two possible spellings for acoustically CVCVCV words, where the middle vowel was suspected to be intrusive; the speakers chose CVCCV spellings, confirming that the middle vowel was not mentally present for them. However, the most widely available evidence regarding the behavior of intrusive vowels is phonological. We have already seen some of the patterns that can be used to test whether a vowel sound is syllabic, including language games, minimal word requirements, and syllable-counting allomorphy. Another diagnostic of whether a vowel is syllabic is whether it causes a preceding vowel to behave like it is in an open syllable. Intrusive vowels fail to trigger open-syllable lengthening in a preceding vowel in Plougrescant Breton, so that 'much' is [kaləs]

³This is not to say that a listener's perception of a syllable is never relevant. A perceived syllable may affect language change or loanword adaptation, by providing an ambiguous input ripe for reanalysis. If learners mistake a transitional schwa-sound for a vowel, then it could be reanalysed as an extra syllable (Fleischhacker 2000).

⁴A similar pattern of syllable-counting allomorphy ignoring intrusive vowels occurs in Armenian, where a word like [tʰusdəŋ] 'daughter' selects a plural morpheme that only attaches to monosyllables (Vaux 2003:105).

rather than *[ka:ləs] (Jackson 1967:64). Stress also depends on syllable count, and intrusive vowels are ignored for stress in languages such as Chamicuro (Parker 1994) and Spanish (Garcia-Bellido 1999). Pearce (2004) shows that intrusive vowels do not undergo iambic lengthening in Kera. However, using invisibility to stress as a diagnostic for intrusive vowels is somewhat tricky. Epenthetic vowels tend to repel stress, although they are not actually invisible for the stress system (see Broselow 1999's analysis of Selayarese, which avoids footing epenthetic vowels but does stress them if necessary to satisfy certain prosodic constraints). It is not always possible to determine whether a vowel is categorically invisible for stress or merely repels stress. This makes stress behavior probably the least useful phonological diagnostic for intrusive vowels.

The idea that an audible vowel sound may fail to count as a syllable is not new, but is not widely accepted either. Non-syllabic behavior is frequently acknowledged for the kind of short, schwa-like intrusive vowels that are sometimes described as 'open transitions' between consonants (Bloomfield 1933), such as appear in Piro, Moroccan Colloquial Arabic, Sierra Popoluca, and Imdlawn Tashlhiyt Berber. It is more controversial in the cases of intrusive vowels that are relatively long in duration or have distinct qualities, like those of Scots Gaelic or Hocank, although for these, too, there are previous proposals that they are non-syllabic (e.g., Clements 1991, Alderete 1995, Bosch 1995, Smith 1999). The following subsections look at three of these controversial cases: Dutch, Hocank, and Scots Gaelic. These languages are chosen for a more detailed look precisely because the intrusive vowels are often assumed to be syllabic, despite acting as phonologically absent in various ways.

3.2 Dutch

Some dialects of Dutch have intrusive schwa between [l] or [r] and non-coronal consonants, as in [hɛləp] 'help', [hɛrəfst] 'autumn', and [kələm] 'quiet' (Booij 1995). For many speakers, the presence of this schwa is optional (Kuijpers & van Donselaar 1997). Kager (1990:244) describes intrusive schwa as shorter than regular Dutch schwa, but an anonymous reviewer disagrees. I do not know of experimental evidence confirming or disconfirming Kager's claim. It may be, of course, that the duration of the schwa (and perhaps even its intrusive status) differs by dialect.⁵ There is controversy over whether to analyze these vowels as syllabic.

One phonological peculiarity of intrusive schwa is that it fails to trigger a process of [n]-deletion that occurs after regular schwa. In the following words, which have underlying schwas, the coda [n] is optionally omitted.

⁵One piece of evidence about duration comes from Donselaar et al. (1999:65,67), who recorded tokens of the same words pronounced deliberately with and without the optional schwa (e.g., [tʏlp] and [tʏləp] for 'tulip') to use as stimuli in a perception experiment. The stimuli were measured in order to determine subjects' reaction times, and it was found that the words were no longer in duration when pronounced with schwa than without. This doesn't bear directly on the question of whether intrusive and lexical schwa differ in duration, but does seem consistent with the idea that vowel intrusion is a rearrangement of gestures within the syllable rather than addition of a syllable.

(11)	Dutch [n]-deletion		Booij (1995:139)
	<i>regen</i>	reɣən ~ reɣə	‘rain’
	<i>gouden</i>	ɣɔudən ~ ɣɔudə	‘golden’
	<i>lopen</i>	lopən ~ lopə	‘to walk (pres. pl./inf.)’
	<i>openlijk</i>	opənlək ~ opələk	‘openly’

I analyse this deletion of [n] as part of the wider pattern in which Dutch schwa restricts what types of coda may follow it. If the purpose of [n] deletion is to avoid [ən] rhymes, then [n] should not delete after a non-syllabic schwa. This is in fact the case. For example, *hoorn* ‘horn’ can be pronounced [horən], with an intrusive schwa. *Horen* ‘to hear’ is also pronounced [horən], but the schwa is underlying and segmental. Deletion of [n] applies only in *horen*, so that many speakers have [horə] but [horən].

(12)	Dutch [n]-deletion		
	<i>hoorn</i>	/horn/ → [horn] ~ [horən], *[horə]	‘horn’
	<i>horen</i>	/horən/ → [horən] ~ [horə]	‘to hear’

Since the intrusive schwa is not a segment, there is no [ən] rhyme to violate phonotactic constraints in [horən].

Intrusive vowels also act non-syllabic for licensing lexical tone contrasts, in dialects that have such contrasts. In Venlo Dutch, lexical high tone can occur on stressed syllables whose rimes contain two sonorant moras, i.e. syllables containing a long vowel, a diphthong, or a short vowel with a sonorant coda (Gussenhoven & van der Vliet 1999:101). Syllables whose rimes contain only a short vowel, or a short vowel followed by a non-sonorant coda, do not contrast for tone. Lexical tone does occur on syllables with vowel intrusion, like [ɛrəm] (meaning ‘arms’ with lexical tone; ‘arm’ if without tone). If the schwa were syllabic, then the stressed syllable would consist only of [ɛ]. Being a single short vowel, this syllable would be monomoraic and would not be expected to license tone. But if the whole sequence [ɛrəm] is a single syllable, it is bimoraic due to its sonorant coda [rm], and its ability to license tone is normal.

There is little published evidence on whether speakers consider intrusive schwa a syllable. Donselaar et al. (1999) conducted an experiment in which listeners were asked to reverse monosyllables segment by segment, changing [tap] to [pat], but reverse disyllables syllable by syllable, changing [hotɛl] to [tɛlho]. Subjects treated words with vowel intrusion as monosyllables over 90% of the time, changing [tɪlɛp] ‘tulip’ to [plɪt] rather than [lɛptɪ]. The authors conclude that ‘the realizations of real words with schwa epenthesis are represented by listeners as monosyllabic.’ A possible problem with this experiment is that subjects might be making use of Dutch spelling, in which intrusive vowels are absent (i.e., subjects may be reversing the letters of the orthographic form *tulp*). However, Warner et al. (2001:389) report that Goetry et al. (2001) have found that preliterate Dutch children judge words with intrusive schwa to be monosyllabic about half the time, in contrast to words with underlying schwa. This suggests that the children have

representational differences between intrusive and lexical schwa that are not attributable to orthography (although the optionality of intrusive schwa could influence the children’s responses.)

The possibility of a gestural analysis of Dutch schwa-insertion has been raised by Donselaar et al. (1999:74), who suggest that ‘from the speakers’ point of view, schwa epenthesis may not arise via insertion of a segment as such, but simply via realization of the gestures corresponding to articulation of the consonant cluster’. This possibility is also raised, but rejected, by Warner et al. (2001), who present an articulatory study showing that /l/ is generally onset-like before an intrusive [ə]. However, for three of their seven subjects, there were significant articulatory differences between the /l/ of words like the name [vɪləm] (with underlying schwa) and [fɪləm] ‘film’ (with intrusive schwa). This is consistent with the idea that for at least these speakers there is a phonological difference between the two schwas.

3.3 Scots Gaelic

While in many languages intrusive vowels are short in duration, they can also be quite long. Scots Gaelic has intrusive copy vowels (often called svarabhakti) in many heterorganic RC clusters, where R is a sonorant, as in [karabad] ‘wagon’, [kanap] ‘hemp’, and [imɪray] ‘to mention’ (Oftedal 1956:142–3). In the Argyllshire dialect, the intrusive vowel is short and transcribed as schwa, but in Outer Hebrides dialects like Leurbost, Bernera and Barra, the intrusive vowel is a copy of the preceding vowel and is as long as, or even longer than, a regular unstressed vowel in the same position (Bosch & de Jong 1997). Yet, the whole CVRVC sequence behaves as a monosyllable, as argued by Bosch (1995), Hind (1996) and Smith (1999).

Early fieldworkers noticed that speakers had unexpected intuitions about intrusive vowels. Borgstrøm (1940:153) reports that when asked to divide a long word into syllables, speakers treated an intrusive vowel as belonging to the same syllable as the preceding vowel. Speakers would not pause before an intrusive vowel when asked to pause between syllables:⁶

Comparing the two words *fæNak* “a crow”... and *f[aLa]k* “hunting”... [a consultant] said: In *fæNak* there is a “space” between the two syllables, so that he could pronounce *fæN — ak*. In *f[aLa]k* the *L* and the following *k* are so “close together” that such a separation is impossible; the word is “nearly monosyllabic, but not quite monosyllabic.”

Oftedal (1956:29) reports that some speakers do call such words monosyllables:

⁶In Borgstrøm’s transcriptions, square brackets enclosing a VCV group indicate that the second vowel is intrusive. *N* and *L* indicate [n, l] with secondary velarisation. Except in quotations, I have standardised the transcriptions to show velarisation as [-] and palatalisation as [j], following Bosch & de Jong (1997). These transcriptions are phonological; the phonetic realisations of these contrasts differ from dialect to dialect, as described by Borgstrøm and Oftedal.

[S]varabhakti groups are recognized as monosyllabic by educated native speakers. This may be partly due to the spelling, where the second vowel of a svarabhakti group is left out (orm, falbh); but it is significant that in songs, even local òrain that have never been written down, a svarabhakti group is sung on one note.

Phonologically, CVRVC sequences pattern as monosyllables. Smith (1999) points out that in the Argyllshire dialect, there is evidence that an RəC sequence with vowel intrusion is still a coda. In this dialect, short stressed open syllables (which are normally initial) are followed by an epenthetic glottal stop, unless the following consonant is an obstruent, as shown in (13a). The function of this epenthetic coda is apparently to make the stressed syllable heavy, a common phenomenon sometimes analyzed with the constraint STRESS TO WEIGHT (Kager 1999). As shown in (13b), glottal stop epenthesis does not occur after long vowels or diphthongs, or in closed syllables, because these syllable types are heavy already. Epenthesis also does not happen in syllables with an intrusive vowel, as shown in (13c).

(13)	Argyllshire Gaelic [ʔ] epenthesis		Holmer (1938)		
a.	/k ^h araxəy/	→	k ^h aʔraxəy	‘move, stir’	
	/u/	→	‘uʔ	‘egg’	
b.	/mɛ:ri/	→	‘mɛ:ri	name	
	/t ^h rai/	→	‘t ^h rai	‘beach’	
c.	/menv/	→	‘menəv	*‘meʔnəv	‘fine, small’
	/marv/	→	‘marəv	*‘maʔrəv	‘dead’

If intrusive vowels are non-syllabic, the lack of [ʔ] epenthesis is expected: [‘menəv] is a single closed syllable, hence heavy without an epenthetic [ʔ].

Another indication that the intrusive vowel is not syllabic is that it can license a range of vowel qualities that is normally possible only in an initial syllable (Bosch 1995; Bosch & de Jong 1997), suggesting that it is in fact part of the initial syllable. Scots Gaelic permits nine short vowels in initial syllables, and a reduced inventory elsewhere. This distribution is in keeping with the cross-linguistically common pattern of allowing more contrasts in ‘privileged’ positions such as root-initial or stressed syllables (see Beckman (1998) and references therein). Intrusive vowels are attested in eight of the nine qualities (Oftedal 1956:140 suggests that the lack of [o] is an accidental gap); they do not undergo the neutralisation of quality that is expected in non-initial syllables. For example, non-intrusive [u] occurs in non-initial syllables only as a result of optional vowel harmony, as in [turəs] ~ [turuus] ‘journey’ (Oftedal 1956:147), but many words have intrusive [u], such as [uɪuɪxəɪ] ‘a shot’, and the intrusive [u] does not have an optional schwa pronunciation. If the intrusive vowel formed a separate, epenthetic syllable, then it would be odd to find this syllable licensing a greater range of qualities than an underlying syllable in the same position. But if the two vocalic periods are actually one vowel,

and belong to one syllable, it is not surprising that they both show the range of vowel qualities associated with the word-initial syllable.

CVRVC also patterns with monosyllables for morpho-phonological mutations. Some words pluralise, or realise other inflections, by palatalising their final coda as well as raising and/or fronting the preceding vowel. The words in (14a) show that the palatalisation mutation affects only the final rime of the word; it doesn't change medial consonants. Yet when a word with vowel intrusion undergoes mutation, as in (14b), both vowels change, and both the sonorant and following consonant palatalise.

(14)	Bernera Gaelic palatalisation	Borgstrøm (1940)
	Singular Plural	
a.	baɫəx baɫiç 'boy'	
	səɫəs səɫiʃ 'light'	
	aɫt ulʲtʲ 'knuckle'	
b.	baɫag bulʲuɡʲ 'bellow'	
	skarav skvøɟʲv 'cormorant'	

This pattern suggests that the whole VRVC sequence is considered one rime.

Finally, vowel intrusion interacts with syncope in a way that can best be explained if the intrusive vowels aren't syllabic (Smith 1999). Many disyllabic stems undergo syncope before vowel-initial suffixes, as in (15a). This syncope can be analyzed as a strategy for avoiding sequences of unstressed syllables: it creates a 'σσ sequence instead of a 'σσσ one. When syncope brings together two consonants of the type that trigger vowel intrusion, an intrusive vowel occurs in the cluster, as shown in (15b). (The ð/r and b/v alternations seen in these examples are mutation processes distinct from the syncope).

(15)	Leurbost Gaelic syncope	Oftedal (1956:183,189)
a.	/obəð + əx/ →	'obrəx 'work (gen.sg)'
b.	/baɫəx + u/ → (baɫxu) →	'vaɫaxu 'boy (voc.pl)'

This interaction is problematic in any approach that tries to explain phonological alternations in terms of the output structures they create. If the insertion of [a] in (15b) created a new syllable, it would undo the effect of the previous syncope, so that the two changes together would only bring the word back to the same CV structure that it had in the input. No improvement in output would be achieved, so the two changes would be unmotivated. But if the intrusive vowel is not a syllable nucleus, then the goal of the syncope is met: there is no sequence of unstressed syllables. The output ['vaɫaxu], like ['obrəx], is disyllabic.

Turning to phonetics, Ladefoged et al. (1998) show that CVRVC has the same pitch pattern as monosyllables, confirming Oftedal (1956)'s description. Pitch rises during the first syllable of a Scots Gaelic word and falls during the second, so that disyllables like [du.an] 'hook' or [baɫak] 'skull' contain a rise and fall, while monosyllables like [duan] 'song' have only a rise. Words with vowel intrusion

have the pitch pattern associated with monosyllables: in [bałak] ‘belly’, pitch rises throughout. Bosch & de Jong (1997) present similar data from natural speech.

Bosch (1995) and Hind (1996) both argue for gestural analyses of vowel insertion. Earlier, Borgstrøm (1938:38) also described intrusive vowels in gestural terms:

In certain groups of comparatively open and sonorous consonants as *-rw-*, *-lx-*, etc., there was an interval between the two articulations during which the tongue was for a moment in an intermediate and relatively open position. This interval was not part of any of the consonants; its nature was more vocalic than consonantal. Part of the vowel preceding the consonants could penetrate into this “vocalic point”; the one vowel was divided into two parts, and the new vowel-part had as much stress as the other, since they were felt to be only one vowel, or at any rate one syllable.

Hence, the gestural representation in (1) is only a new formalisation of an old insight about the structure of these words.

3.4 Hocank

Another example of relatively long intrusive vowels comes from the Siouan language Hocank (also known as Winnebago). Hocank has intrusive copy vowels in CR onsets, where R is a sonorant.⁷ Examples include [ʃawaʃi] ‘you dance’ and [hiperes] ‘know’. Alderete (1995) and Clements (1991) have analyzed these vowels as non-syllabic; Clements also gives a gestural analysis.

The evidence for non-syllabicity comes primarily from templatic morphology. Hocank has a pattern of reduplication that copies the final syllable of a stem, as in (16a). If a final CRV sequence has vowel intrusion, the whole CVRV sequence reduplicates, as in (16b). This is expected, if it is one syllable.

(16)	Hocank reduplication		Miner (1992), Susman (1943)
	a.	gihú ‘swing’ gihuhú ‘wag tail’	
		waʃí ‘dance’ waʃiʃí ‘dance, stop, dance again’	
	b.	ʃará ‘bald, bare’ ʃaraʃára ‘bald in spots’	
		paraś ‘flat’ parapáras ‘wide’	

Similarly, most roots in Hocank are clear monosyllables of the form CVC or CVV. The only exceptions are CVRV roots where the first vowel is intrusive; other CVCV sequences are not possible roots. If intrusive vowels are non-syllabic, we can maintain the simple generalisation that roots are limited to one syllable.

Another phonological phenomenon for which the intrusive vowel fails to act like an independent syllable is final-syllable ablaut. Many stems change their final

⁷In examples below, I reproduce the broad transcription that is used by the sources quoted, but it should be noted that Susman (1943) describes the ‘[r]’ as articulatorily a flap.

[a] to [e] before certain suffixes. This ablaut normally affects the last syllable of the stem, as shown in (17a). But when the final syllable has vowel intrusion, both the intrusive vowel and the following vowel undergo ablaut, as shown in (17b).

- (17) Hocank ablaut Miner (1992)
a. hīxe hīxawi ‘he buries me, he buries us’
b. kere kəraire ‘depart returning, 3pl.’

This is expected, if the two vowels are both part of the final syllable and are two time periods of a single gesture.

Although instrumental studies are not available, fieldworkers report that CVRV differs in duration and pitch from ordinary, disyllabic CVCV. According to Miner (1979), ‘the sequences are spoken (and apparently, sung) faster than other CVCV sequences.’ Susman (1943), who dubs them ‘fast sequences’, comments that ‘in most surroundings, [CVRV] is intermediate in length between one long and two short syllables,’ and that ‘secondary stress [accent] seems to attach equally to both syllables’ of CVRV. The treatment of intrusive vowels in the accentual system is too complex to cover here, but as Hayes (1995:362) notes, his account of Hocank accent is compatible with Clements (1991)’s analysis of CVRV sequences as monosyllabic. The details of combining these approaches are worked out in Hall (2003).

Intrusive vowel sequences have different pitch patterns than disyllables, although the nature of this difference is disputed. An ordinary disyllable has accent on the second syllable. For words like [kere] ‘depart returning’, the descriptive literature contains three transcriptions of accent: [kèré] (Miner 1979), [kére] (Lipkind 1945), and [keré] (Miner 1992). Miner (1979) explains that ‘perceptually... it sometimes happens that the secondarily accented syllable has almost as much accent as, or even as much as (but never more than) the primarily accented one. It may be this that caused [Lipkind 1945] to write stress only on the C₁V₁ portion of fast sequences.’ Pitch tracks of individual tokens in Hall (2003:173) support Miner’s description: the two vowels in CVRVC have fairly even pitch, but in disyllabic CVCVC the second vowel has a much higher pitch than the first. While a more extensive instrumental study is needed, it seems clear that there are phonetic differences between CVRVC and ordinary CVCVC. These differences could relate to CVRVC being monosyllabic.

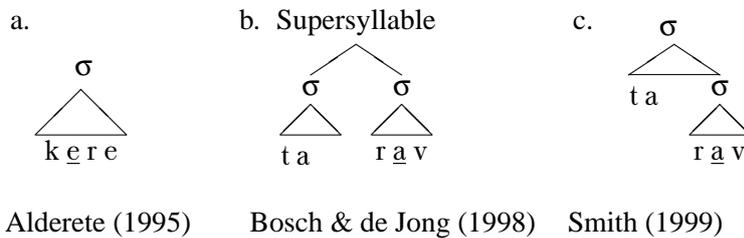
4 Vowel intrusion and representing syllable structure

If we accept that intrusive vowels do not add a syllable to the word, this raises the problem of how to represent the internal structure of monosyllables that are acoustically CVCVC-like.

One possible line of analysis is to assume that syllables can have a more complex internal segmental structure than is usually believed. Some proposals of this

type are summarised in (18). Alderete (1995) simply proposes that Hocank syllables can contain non-adjacent vowel segments. Bosch & de Jong (1998) propose a unit called a supersyllable in Scots Gaelic, which dominates two syllables yet itself counts as a single syllable for some purposes. Smith (1999) analyses Scots Gaelic as containing recursive syllables, where one syllable forms the coda of another. Smith gives a highly articulated X-bar representation of the syllable; the diagram in (18c) reflects only the N'' (syllable) constituents.

(18) Representations of "CVCV(C)" monosyllables



All of these proposals treat the intrusive vowel as a phonological segment, and then expand the range of possible syllable structures to allow syllables with non-adjacent vowel segments. There are at least two disadvantages to such approaches, however. First, any expansion of the organisational principles of the syllable makes the theory of syllabification considerably less restrictive. Without additional theoretical apparatus to constrain the use of structures like recursion or supersyllables, the number of syllable types that such theories can generate is undesirably large. Secondly, the typological characteristics of non-syllabic vowels enumerated in (2) do not naturally fall out of these representations, without further theoretical assumptions. Intrusive vowels tend to occur between heterorganic consonants, copy only over sonorants, and be sensitive to speech rate. There is not an obvious, theory-independent reason why such properties would be associated with any of the structures in (18). This is not to imply that such concerns cannot be addressed; Smith, in particular, proposes recursive syllables in the context of a larger theory of syllable structure which does include restrictions on recursion. But it is worth looking for a way to represent intrusive vowels that captures the widespread insight that they are more ‘phoneticky’ than other vowels, and which relates their special characteristics to their phonetic nature.

The theory of Articulatory Phonology has introduced representational elements, namely abstract articulatory gestures, that make such an analysis possible. Section 4.1 reviews gestural representations, and section 4.2 proposes a representation for intrusive vowels in terms of gestures and segments.

4.1 Gestural representation

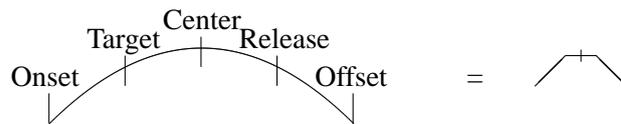
Articulatory Phonology (Browman & Goldstein 1986) models phonological processes as changes in the timing or magnitude of articulatory gestures. In its full

form, Articulatory Phonology consists of both a new gestural representational system, and a theory of the kind of operations that can act on these representations. However, like a number of researchers, I will argue for using the gestural representations as a descriptive device while not subscribing to the fuller theory of Articulatory Phonology. I will also augment the gestural representations with the more traditional representational units of segments and syllables.

A gesture is an abstract temporo-spatial specification of a constriction within the vocal tract. The spatial aspect of the representation consists of variables for location of constriction and degree of constriction. The sound transcribed [t], for example, requires the gestures [tongue tip alveolar closure] and [glottis wide]. The temporal aspect of the representation includes in some versions of the theory (e.g. Gafos 2002) a series of temporal landmarks: the ONSET of movement, the TARGET, when maximal constriction is reached, the CENTER of the constriction phase, the RELEASE of the constriction, when the articulator begins a controlled movement away from the target position, and the OFFSET, when the articulator ceases to be under active control. For simplicity, the gestural curve may be drawn with angles to represent the landmarks, as shown below right.

(19) Landmarks in gestural life

Gafos (2002)



The temporal structure of gestures is what most significantly distinguishes them from features or segments. While features and segments can only be linearly ordered, gestures can overlap one another. The grammar determines the degree of overlap by specifying an alignment of landmarks in two gestures. For example, in a sequence of two consonants, the grammar might specify that the center of the first consonant should be simultaneous with the onset of the second. A specified degree of overlap is called a phasing relationship, and a sequence of gestures with specified phasing relationships is a gestural score.

It is possible to test the acoustic result of a given alignment of gestures at a particular speech rate. Simulations are done with a computational gestural model called GEST, developed at Haskins Laboratories (Browman & Goldstein 1990a). A model of task dynamics, based on a general theory of skilled motion, converts the gestural representation to articulatory trajectories. Once the articulatory trajectories are calculated, an articulatory simulator converts these trajectories to an acoustic output. This paper does not report on any new simulations, but will relate typological findings to results of simulations described in the literature.

4.2 Proposed representation of vowel intrusion

The theory of Articulatory Phonology does not only consist of a gestural representational system; it is also a theory of the type of changes that can occur between

lexical forms and surface forms. In its strongest form, Articulatory Phonology does not allow insertion, deletion, or reordering of gestures. Only changes in the magnitude of gestures in time and space, or changes in the phasing relations of gestures, are allowed. Browman & Goldstein (1990b) show that some casual speech phenomena traditionally described as insertions, deletions, or assimilations can indeed be more accurately described as gestural changes. For example, the phrase *perfect memory* is sometimes pronounced without an audible [t], yet X-ray data reveals that the alveolar gesture associated with [t] is still present. It is simply overlapped by other gestures to the point that it has no acoustic effect. This ability to distinguish articulation from acoustics is an important advantage of gestural representations.

However, several researchers have argued that the strong form of Articulatory Phonology is too restrictive to capture the full range of phonological phenomena. Changes in gestural phasing can model non-categorical processes, such as partial assimilations, but cannot model categorical processes. Any categorical alternation, where related forms differ in the number or identity of gestures they contain, must be analysed in a strict Articulatory Phonology theory as involving multiple lexically stored allomorphs. This solution often seems cumbersome, as it relegates to the lexicon many alternations that are highly regular and common. Partly to avoid this problem, McMahan et al. (1994) propose a framework which combines gestural representations with a Lexical Phonology system of derivation. They argue that the prohibition on addition, deletion, and permutation of gestures should only apply at a late stage of derivation: categorical processes happen first, and gradient processes afterwards.

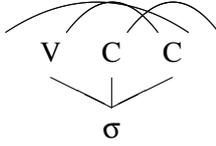
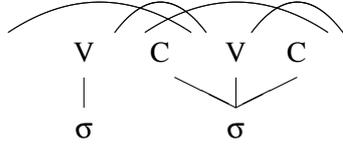
Zsiga (1997) makes similar points in a non-derivational framework. She proposes that gestures are associated with features. Categorical processes occur when features undergo autosegmental processes of association and disassociation, and gradient processes occur when gestures shift alignment. The use of abstract features is in itself an addition to the original form of Articulatory Phonology, which dispenses with many of the representational elements that are common in other frameworks, such as syllables, segments, features, and morae.

Capturing the distinction between epenthetic and intrusive vowels raises similar problems to those addressed by McMahan et al. and by Zsiga. The analysis needs to capture the fact that vowel epenthesis is a categorical process, while vowel intrusion is more gradient, and also needs to explain why epenthetic vowels act like syllable nuclei while intrusive vowels do not. To capture these differences, I propose using a representational system similar to that of Zsiga. This representation, shown in (20), incorporates abstract syllables and segments, as in traditional accounts, as well as a gestural layer to allow description of gradient, phonetic effects. In (20) I show gestures only as part of the surface representation, not the underlying representation, but this is not a crucial assumption.

Epenthesis occurs when a segment is added to the representation. An epenthetic segment is associated with its own gestural material, and hence may have a phonetic quality that is not dependent on that of surrounding sounds. Vowel intrusion is a phenomenon that concerns only the gestural layer of the representation, and oc-

curs when the phasing of existing gestures produces a vowel-like percept. It does not involve addition of a vowel segment. Syllable nodes organise segments, and hence the presence of intrusive vowels is irrelevant to syllable count. The structure of the syllable itself is familiar and traditional, without recursion, non-adjacent vowel segments, etc.

(20) Proposed representations

	Vowel Intrusion	Epenthesis
Underlying	/VCC/	/VCC/
Surface		
Transcription	[VCVC] / [VC ^V C]	[VCVC]

Two possible transcriptions are given for the intrusive vowel above because either transcription might be found in descriptive literature. Some fieldworkers use devices such as superscripting to show short duration; others do not.

The representation in (20) helps to explain a number of the cross-linguistic distributional characteristics of non-syllabic vowel sounds, such as their typical restriction to heterorganic clusters and their tendency to disappear at fast speech rates. These characteristics will be discussed further in section 5. The representation also captures the fact that a vowel may be acoustically present without being a phonological entity. Treating the intrusive vowel as a phonological non-entity accords with its general phonological invisibility, and also explains why intrusive vowels are not used to repair syllable structure, as discussed below.

4.3 Motivation: repair or perceptibility?

According to the theory proposed above, vowel epenthesis and vowel intrusion are different operations on a physical level. It is natural that their motivations, and the environments in which they typically happen, may also differ. In this section I outline the theory that vowel intrusion is driven by the need to make consonants in clusters perceptible. Epenthesis, on the other hand, is a way of repairing syllables that violate a language's abstract structural rules.

There is reason to believe that an intrusive vowel helps the listener to better perceive the consonants in a cluster. Researchers in Articulatory Phonology have argued that one factor determining gestural phasing is the need to make gestures perceptually recoverable (Silverman 1995; Wright 1996; Chitoran et al. 2002). A gesture's recoverability is compromised when its acoustic cues are weak or absent,

for example due to overlap with other gestures. Consonant clusters pose a problem for perceptibility, because CV and VC transitions convey information about consonant place. If a consonant transitions directly into another consonant, there is no CV transition for the first consonant, and no VC transition for the second. However, the perceptibility of the adjacent consonants is increased if there is a release burst between them. The release burst can carry some articulatory information about the consonants. A burst that is voiced and has vocalic characteristics—i.e., an intrusive vowel—should be particularly suited to convey articulatory information about the adjacent consonants.

The idea of a perceptual motivation for intrusive vowels has been raised by researchers on several of the individual languages that have intrusive vowels. Donselaar et al. (1999) present experimental evidence that in Dutch, the optional intrusive schwa aids perception when it is present. Listeners' reaction times to lexical decision tasks and phoneme identification tasks are quicker when a word like *tulp* 'tulip' is pronounced with vowel intrusion ([tʏlɔp]) than without ([tʏlp]), even though [tʏlɔp] is less canonical. Bradley (2002:105) argues that an intrusive vowel provides optimal acoustic conditions for perception of taps in clusters in languages such as Spanish. Without the intervening vowel fragment, the short constriction of the tap might not be noticed. Taps or flaps are, in fact, among the most common triggers of vowel intrusion cross-linguistically.

There is a need for more work on how vowel intrusion affects perceptibility of consonants in individual languages. One question is how the distribution of intrusive vowels in a given language relates to that language's phonemic inventory, phonotactic rules and phonetic characteristics. For example, Borgstrøm proposes that intrusive vowels developed in sonorant-initial clusters in Scots Gaelic precisely in order to maintain a perceptual distinction between the exceptionally large number of sonorants in the language. Gaelic once contrasted palatal and non-palatal, lenited and non-lenited forms of *l*, *n*, *r*, and *m*, some of which still exist. Borgstrøm suggest that 'the distinction of these four qualities necessitated a particularly clear and accurate articulation; this led to an increase of the interval between the consonants... and determined the insertion of a vowel' (Borgstrøm 1938:130). Borgstrøm's suggestion is intriguing, because it relates a language-particular distribution of intrusive vowels to that language's system of phonological contrasts. This is what we might expect if vowel intrusion indeed has a perception-enhancing function: it should appear where it is most needed to maintain important contrasts, which may be different in different languages. It is beyond the scope of this paper to present detailed case studies of the environments for vowel intrusion in individual languages, but an application of Borgstrøm's approach to other languages might help to explain language-specific patterns of the distribution of intrusive vowels.

One fact that seems to hold cross-linguistically about the distribution of intrusive vowels is that, unlike epenthetic vowels, they do *not* appear preferentially in the most marked consonant clusters a language has. Languages usually prefer that sonority rise within an onset cluster and fall within a coda cluster (see Ohala 1990b for the history of this observation). In heterosyllabic clusters, falling sonority is

preferred, as stated in the Syllable Contact Law of Vennemann (1988). Underlying clusters that don't meet these requirements are the most frequent targets for repair via deletion, epenthesis, or other processes.

Yet cross-linguistically, intrusive vowels do not show any tendency to target marked cluster types more than unmarked cluster types. To illustrate this, (21) gives the full list of initial clusters in Hocank, final clusters in Scots Gaelic, and heterosyllabic clusters in Finnish, divided into those that do and don't have vowel intrusion. In each language, the clusters with vowel intrusion include some of those that are the least marked in terms of sonority sequencing for their position. Hocank has intrusion in obstruent-sonorant onsets but not in obstruent-obstruent onsets. Scots Gaelic has intrusion in some sonorant-obstruent codas but not obstruent-obstruent codas. Finnish has intrusion in some heterosyllabic clusters of falling sonority but not in those of rising sonority, although the Syllable Contact Law states that falling sonority is preferred in heterosyllabic clusters.

(21) **Hocank onset clusters** (Miner 1993)

With intrusion pn pr kn kr kw sn sr sw ʃn ʃr ʃw
tʃw xn xr xw

Without intrusion ps pʃ ks kʃ kdʒ st sg ʃg ʃdʒ xg
xdʒ tʃg pʔ tʔ kʔ sʔ ʃʔ xʔ

Scots Gaelic (Leurbost dialect) coda clusters (Oftedal 1956:48, 142)

With intrusion ɫb rb np ɫp lgʲ ɛgʲ rʲgʲ ɫg rg ɲk ɛk
nv ɫv lv rv rʲv rf mç ɲç nç rʲç ry ɲx nx ɲʲx
ɫx ɫʲx rx rʲx mʃ nm ɫm lm rm rʲm mn mr lj rʲj

Without intrusion dʲʃ tʲʃ gʲʃ jp rp ɛd ɛt rʲtʲ rʲkʲ rk
ɫt ɫʲtʲ lkʲ ɫk mb ɲd ɲt ɲʲdʲ ɲʲgʲ ɲg ɲk sd ʃdʲ ʃdʲ
ʃgʲ sg ʃd çdʲ xg ɛs ɛn

Finnish heterosyllabic clusters (Harrikari 1999)

With intrusion hv hj hm hn hl hr lk lv lj lh lm lp

Without intrusion hk ht kl kr ks ps pl pr tk tr tv
tj sk sl sm sp sv ts lt ls mp ns nt ŋk rn rt rs
st

In each language above, the clusters targeted by vowel intrusion include some of those that real structure-changing processes would be most likely to leave alone, and in fact do leave alone. The same is true in other languages. As Donselaar et al. (1999:60) note of Dutch:

There appears to be no pressure to avoid clusters in other optional processes. For instance, nicknames and other word formation processes in Dutch do not avoid clusters—thus someone named *Marcus* can be known as *Marc*... and someone with the function of *directeur* (“director”) may be referred to as the *dirk*.

If Dutch wanted to avoid clusters like [rk], it could truncate these words to *Mar* and *dir*. The fact that Dutch does not use truncation to avoid clusters like [rk] supports the idea that these clusters are not highly marked, and that the intrusive schwa that optionally appears in these clusters is not there to repair the clusters.

A reviewer suggests that the claim that vowel intrusion occurs in unmarked clusters is circular, since the presence of vowel intrusion in these clusters could be brought as evidence that they *are* marked. The important point, however, is that vowel intrusion differs from a group of other processes in the kind of clusters it targets. Phonological processes like deletion, epenthesis and metathesis tend to be fairly consistent as to which types of consonant clusters they remove, both cross-linguistically and within languages. Vowel intrusion is the odd one out.

According to the theory proposed here, the reason that vowel intrusion does not particularly target marked clusters is that it has no power to repair these clusters. When a cluster is heard with an intrusive vowel, the cluster is still phonologically intact, as a segmental string. So if a language disallows, for example, rising sonority codas, then VCR and VCVR are equally illegal, because CR forms a coda in both cases.

The idea that gestural effects do not achieve repairs has been proposed before: Warner et al. (2001:416) suggest that whether an insertion pattern has a repair function is a basic diagnostic for whether it is gestural in nature (see also Levin 1987:192). They suggest that sound insertion that brings syllable structure closer to a CV pattern is more likely to involve insertion of a phonological unit, while other types of insertion (such as the intrusive [t] in *mince* [min^ts]) may involve only adjustments to gestural timing. The present survey corroborates the observation that gestural phenomena do not have a repair function, but does suggest that “bringing syllable structure closer to a CV pattern” is too broad a criterion for concluding that a process has a repair function. Both epenthetic and intrusive vowels occur in underlying CC clusters, and hence, on an acoustic level, create CV patterns. The difference between them is that epenthetic vowels are most likely to occur in the most marked types of CC clusters that a language contains, while the distribution of intrusive vowels is unrelated to the markedness of the clusters.

5 Typology of vowel intrusion

This section will show how the gestural analysis accounts for some typological characteristics of intrusive vowels, namely a) why they are either copy vowels or neutral and schwa-like in quality; b) why they are typically restricted to heterorganic clusters; and c) why they are likely to disappear in fast speech. Each of these characteristics falls out from independently motivated properties of gestural phonology.

5.1 Quality of the intrusive vowel

Research in speech synthesis and articulation shows that when two consonants are phased to have a low degree of overlap, they may sound like they have a vowel between them. This section will review the evidence that vocalic percepts can be produced this way, and show that the range of vowel qualities that can be produced this way matches the qualities found in intrusive vowels.

Perceptual experiments have found that gestural retiming is sufficient to produce what English speakers hear as an extra syllable, without insertion of new phonetic material. Browman & Goldstein (1990a) generated tokens of the word *bray* ([bɹeɪ]), using the GEST model described in section 4.1, and varied the level of overlap between the first two consonants. When overlap between the bilabial and rhotic gestures was reduced, subjects heard *beret*, which can be pronounced [bəɹeɪ] or [bɹeɪ]. Price (1980) achieves similar results using acoustic manipulations of voice onset time and sonorant length. Neither experiment probed whether listeners heard the nucleus of the extra syllable as a schwa or a syllabic liquid, but the results at least support the idea that what a linguist hears as an inserted syllable in another language could plausibly be only a result of gestural timing from the point of view of a speaker of that language.

Gestural retiming can produce vowel percepts of several qualities. Simply reducing gestural overlap in a CC cluster can produce the percept of a schwa. As part of a study examining whether English schwa is associated with a gesture, Browman & Goldstein (1992) tested different ways of producing a synthesized utterance of the acoustic form [pV₁pəpV₂p]. It was found that a schwa-like percept could be produced without a tongue body gesture, if the medial [p]s were phased to have a wide interval between them and this interval was not overlapped by V₁ or V₂. Gafos (2002:271) reports similar results with different synthesized consonant clusters. In a sequence of two heterorganic consonants, a schwa-like sound results when the center of the first consonant is aligned with the onset of the second. This phasing relation can be abbreviated as CENTER = ONSET. Gafos hypothesizes that such a phasing produces the intrusive schwas that occur in Moroccan Colloquial Arabic codas.

Articulatory studies provide evidence that gesture-less schwa sounds are not only theoretically possible, but occur in real speech. Using ultrasound, Davidson & Stone (2003) examined English speakers' productions of non-native consonant clusters in pseudo-Slavic words such as *zgomu*. Some speakers' productions were heard to have a schwa between the consonants ([zəgomu]), but the ultrasound showed no tongue movement towards a schwa-position. Davidson and Stone analyze the acoustic schwa as purely a result of a low degree of overlap between the consonants.

Similarly, Gick & Wilson (in press) show through an ultrasound study that a targetless schwa-sound can result when the tongue moves between adjacent segments that have conflicting tongue body targets. In American English words like *file* /fail/, the tongue body must pass through a schwa-like configuration on the shortest route

from the high front position of the [ɪ] to the low back position of dark coda [ɫ], so that the word sounds like [faɪəɫ]. Lavoie & Cohn (1999) show that rimes containing this schwa are comparable in duration to similar rimes without schwa, such as [ald] and [aɪd], and argue that words like [faɪəɫ] are phonologically monosyllabic. This is a different sort of vowel intrusion than the cases considered here, because it doesn't depend on the degree of overlap between gestures so much as the conflict between gestures. It is, however, another demonstration that a schwa-like percept may be produced without an independent vowel gesture.

It is possible for an intrusive vowel to have a non-schwa quality, but only through the influence of surrounding consonant and vowel gestures. When there is a release between consonants with a phasing like CENTER = ONSET, both of the consonant articulations are active during the period of release: the articulators are moving away from the target constriction of the first consonant and towards the target constriction of the second consonant (see the illustration below in (22)). If any of the gestures associated with the consonants influence the position of the tongue body or lips during the release, the resulting shape of the vocal tract should affect the intrusive vowel's quality. Some intrusive vowels do seem to be coloured this way. Itelmen has intrusive [a] between a uvular consonant and a voiced sonorant (Bobaljik & Wurmbrand 2001). Since uvulars and [a] both involve tongue body retraction, the intrusive vowel's quality probably results from the tongue body gesture associated with the uvular consonant. Similarly, intrusive vowels in Piro are optionally homorganic with adjacent consonants, as in [k^owali]~[k^awali] 'platform' (Matteson & Pike 1958).

The intrusive vowel may also be influenced by the gestures associated with a vowel segment that is adjacent to the consonant cluster. A number of phonetic models claim that consonantal articulations are superimposed on vocalic articulations in speech (Öhman 1966; Perkell 1969; Fowler 1980). If, during the production of a consonant cluster, a vowel gesture is also active, it may affect the shape of the vocal tract and hence colour the acoustic release. This could make the intrusive vowel sound like a copy vowel, as proposed by Steriade (1990) (see the illustration in (1)). Browman & Goldstein (1992) find that overlap between a vowel gesture and a group of consonant gestures does produce such an acoustic effect in synthesized speech. In one set of simulations of [pV₁pəpV₂p], the gestures of V₁ and V₂ were made continuous, such that active control of V₂ began at the end of V₁ (as before, no schwa gesture was present). The authors note that the intended schwa did not sound schwa-like when V₁ and V₂ were the same, particularly if they were high vowels, and give the example of intended [pipəpip] sounding like [pipipip]. This can be seen as a synthesized intrusive copy vowel (although its environment is different from attested intrusive copy vowels; I have not found any case of these copying over [p] in natural language). A similar gestural configuration may produce intrusive copy vowels like those in Table 1.

I am not aware of any articulatory study of intrusive copy vowels that could confirm whether these vowels really do result from a vowel gesture overlapping a consonant cluster. However, Bosch & de Jong (1998)'s acoustic study of Scots

Gaelic provides suggestive evidence. When words of the form CV₁R_V₂C, with intrusive vowels, were compared to ordinary disyllables of the form CV₁RV₂C, the intrusive vowel words had a greater degree of coarticulation between R and V₂. Since the degree of consonant-vowel coarticulation has been analyzed as corresponding with the degree of gestural overlap (Zsiga 1995; Cho 1998), heavier coarticulation of the intrusive vowel with R is expected if indeed V₁ and V₂ belong to a single gesture which fully overlaps R.

In short, the qualities attested in non-syllabic vowels closely match the range of qualities that can be produced through adjustment of gestural timing: schwa, a copy vowel, or a quality homorganic with an adjacent consonant. The gestural account also explains why, as Levin (1987) notes, an intrusive vowel may have a quality unlike that of any lexical vowel in the language's phonological system. Since the intrusive vowel's quality is determined by physical rather than phonological factors, a language with no phonemic schwa can still have an acoustic schwa between consonants.

It should be noted, incidentally, that a low level of overlap between consonants can also produce acoustic effects that do not sound vowel-like. Often, languages that have vowel intrusion in some consonant clusters have effects described as aspiration or consonant syllabification in other consonant clusters. All of these phenomena may be attributed to low gestural overlap. Aspiration between consonants can be seen as a kind of voiceless intrusive vowel. In Sierra Popoluca, for example, intrusive schwa occurs in (most) clusters that are heterorganic, begin with a nasal, and span a syllable boundary, as in [ʔmip^apa] 'he comes'. If a cluster in the same environment begins with a voiceless consonant, that consonant is transcribed as aspirated, as in [ʔkek^hpaʔ] 'it flies' (Elson 1947). As pointed out by Gafos (2002), it is plausible that clusters like /kp/ and /pp/ have the same phasing in Sierra Popoluca, although the period of release sounds like aspiration when it is voiceless and schwa when it is voiced.

Another effect that sometimes co-occurs with vowel intrusion is what Matteson & Pike (1958) call 'non-phonemic syllabification' of a consonant in a cluster. An example of this occurs in Piro, which is described as having intrusive vowels (some voiced, some not) in most consonant clusters. Some of the clusters that do not have vowel intrusion are transcribed instead with syllabification of the first consonant, as in /hiʃpi/ [hiʃpi] 'his lip', yet Matteson and Pike claim that the consonant does not count phonologically as a syllable. We cannot know from written descriptions exactly what this 'syllabification' consists of phonetically, but I suggest that it could be another manifestation of distance between the consonant gestures. The first consonant may sound longer when it has a low degree of overlap with the second consonant. A similar phenomenon is described by Kinkade (1998:199) for Upper Chehalis: when a sonorant follows another consonant, either an intrusive schwa occurs between the words or the sonorant becomes syllabic.

5.2 Restriction to heterorganic clusters

As noted in (2), intrusive vowels tend to occur between heterorganic consonants rather than homorganic consonants. This fact is readily explained if intrusive vowels result from gestural phasing.

The acoustic result of a gestural representation depends not only on the phasing of the gestures, but on the characteristics of the gestures involved. Gafos (2002) reports simulations showing that a phasing relation of CENTER = ONSET produces a schwa-like sound between heterorganic consonants but not between homorganic consonants.

(22) Homorganic and heterorganic clusters, CENTER = ONSET phasing



In the cluster [lt], the tongue tip has the same target constriction for both consonants. At the time when the first target constriction is being relaxed (RELEASE of [l]), the same target is being activated again (ONSET of [t]). The resulting articulatory trajectory has the tongue stay in place. Only if the [t] gesture began after the release of [l] might an acoustic release occur between the two consonants.

So if a language has the phasing CENTER = ONSET for all consonant clusters, vowel intrusion should occur in only the heterorganic clusters. This, by and large, is what we find. In (23) are listed the clusters that have vowel intrusion in Sierra Popoluca and Dutch, and earlier (21) gave the clusters with and without vowel intrusion for Hocank, Scots Gaelic, and Finnish⁸. These lists show that vowel intrusion occurs almost exclusively in heterorganic clusters (some exceptions are discussed below).

(23) Clusters with vowel intrusion

Sierra Popoluca	np	nk	ng	nm	ɲp	ɲk	ɲg	ɲm	ɲp	ɲt
	ɲtʰ	ɲc	ɲtʃ	ɲs	ɲʃ	ɲm	ɲj	ɲɲ	ɲj	
Dutch	lm	rm	lp	rp	rf	lf	lk	rk	lx	rx
	rn									

Non-gestural theories of vowel insertion have to include separate rules for homorganic and heterorganic clusters in each language, but in the gestural approach, this is not necessarily the case. Even if the grammar gives all clusters in a language

⁸In the case of Finnish, Harms (1976:77) seems to support the idea that consonant clusters with and without vowel intrusion have a similar phasing relation. He claims that all sonorant-initial clusters have a 'clear separation between the final consonant of the first syllable and the initial consonant of the following syllable', but that the phonetic realisation of this 'separation' differs depending on the identity of the sonorant: there is a voiced vocoid after [l], a stronger trill on an [r], and a voiceless vocoid after [h]. He explicitly states that in both homorganic and heterorganic clusters, 'the energy of the first syllable is 'spent' before the onset of the next syllable.' This impressionistic description is quite consistent with the idea that RC clusters in Finnish all have the same phasing relation, although this phasing relation produces vowel intrusion only in certain cluster types.

the same phasing, intrusive vowels are expected to arise more easily in heterorganic clusters. In this way, the gestural approach allows a simpler analysis of the intrusive vowels' distribution.

However, there are a few exceptions to the generalisation that vowel intrusion doesn't occur in homorganic clusters. Several concern clusters that include flaps. In Armenian, Hocank, Spanish, and Saami, vowel intrusion occurs between flaps and other coronal consonants. It is likely that the reason for this is the ballistic articulation and extremely short closure phase of the flap, which Catford (1977:130) describes as 'essentially a dynamic, flicking, or hit-and-run motion'. Since the tongue tip touches the upper articulator only briefly, it would take a greater degree of overlap with a neighboring consonant to prevent there being an acoustic release. Other sporadic exceptions concern particular consonant sequences in particular languages. For example, some Dutch speakers have an alveolar realisation of /r/ but still have vowel intrusion in /rn/. There are a few cases where vowel intrusion occurs in homorganic CR but not RC clusters: Mokilese has vowel intrusion in [pwed̪ila] 'lucky', but not in [lolda] 'to become wet'. The explanation for these exceptions is a topic for future research. It may lie in special articulatory characteristics of the clusters involved in these languages, or it may indicate that the grammar sometimes phases certain clusters differently than others. Nevertheless, the tendency of vowel intrusion to be blocked in homorganic clusters is strikingly strong across the typology (in many languages exceptionless), and this is what is predicted by the gestural account.

5.3 Speech rate and stress

A third characteristic of intrusive vowels is that they are often variable in duration, and may disappear at fast speech rates or in casual speech, as reported for Saami (Bye 2001:139), Argyllshire Gaelic (Holmer 1938:32), Finnish (Harms 1976:77), Spanish (Quilis 1981:298), Hamburg German (Jannedy 1994), Moroccan Colloquial Arabic (Heath 1987; Gafos 2002), Mono (Olson 2003), and Chamicuro (Parker 1994). To give an example, Parker notes that in Chamicuro, every form in which a glottal stop is flanked by identical vowels alternates with a form where the second vowel is missing, and that the form with two vowels occurs only in fortis speech. (He analyses the optional copy vowel as 'one possible phonetic implementation of the release of a tautosyllabic glottal stop'—a conclusion quite compatible with the gestural analysis.)

(24)	Chamicuro		Parker (1994)
	Normal speech	Emphatic speech	
	'tuʔlu	'tuʔulu	'chest'
	jap'leʔti	jap'leʔeti	'lightning'
	maʔ'nali	maʔa'nali	'dog'

The greater prevalence of vowel intrusion in slow speech is predicted by the gestural account. Research into speech rate effects on gestural phasing suggests

that acoustic release between consonants is more likely to occur in slow speech, for more than one reason. Speech rate changes can involve several types of gestural adjustment, and speakers vary as to which mechanisms they use to increase speech rate (see the literature review in Davidson 2003:141). One type of change that may occur in fast speech is an increase in gestural overlap (Munhall & Lofqvist 1992; Zsiga 1994; Byrd & Tan 1996; Davidson 2003). If vowel intrusion is a result of low overlap between consonants, a rate-related increase in overlap would support the tendency of intrusive vowels to disappear in fast speech.

Another type of change that occurs in fast speech is a decrease in segmental duration (Gay 1981). Decreased gestural duration can be modeled by increasing a gesture's stiffness, which is part of the equation that describes the gestural curve. Gafos (2002:286) tests the effect of altering stiffness in simulated consonant clusters with the consistent phasing relation $CENTER = ONSET$, which, as noted above, can produce vowel intrusion. He reports that increasing the consonant gestures' stiffness eventually results in the disappearance of the release, even in heterorganic clusters. Hence, even if a consonant cluster has the same gestural phasing at all speech rates, it may have an intrusive vowel only at slower rates.

It should be noted, however, that for CC clusters with a *very* low level of overlap, increasing the stiffness of the gestures does *not* result in disappearance of the release. According to Gafos (2002:293), two consonants with the phasing relation $RELEASE = OFFSET$ will have a release between them regardless of the speed of articulation. This means that an intrusive vowel resulting from an alignment of $RELEASE = OFFSET$ will be present at all speech rates (assuming that the gestural alignment itself remains constant). Gafos (2002) cites this as the reason that certain intrusive vowels in Moroccan Colloquial Arabic are not speech rate-dependent. Other intrusive vowels that are not reported to disappear in fast speech include those of Scots Gaelic, Hocank, and Dutch. Warner et al. (2001:416) propose that whether vowel insertion is dependent on speech rate is a basic diagnostic for whether it involves insertion of a unit (phonological epenthesis) or only gestural retiming. I suggest that while disappearance in fast speech is a sign that a vowel is intrusive, the converse is not necessarily true: a vowel that does not disappear at fast speech rates may also be intrusive, but involve an unusually low degree of overlap between consonants.

The role of stiffness and overlap in determining release may also help to explain another subtrend in the typology of vowel intrusion: the existence of languages where vowel intrusion occurs only in stressed syllables. The phonetic implementation of stress is somewhat similar to that of slow speaking rates. Gestures in stressed syllables have longer durations, which may be attributed to decreased stiffness (Kelso et al. 1985). Stress is also associated with decreased gestural overlap (Harrington et al. 1995). Both of these factors should increase the likelihood of vowel intrusion in stressed syllables, for the reasons cited above.

There are at least two languages, Kekchi and Finnish, where vowel intrusion happens only in stressed syllables. In Kekchi, which has final stress, only word-final [ʔ]C clusters contain intrusive vowels. In (25a), the non-final [ʔt] and [ʔf]

clusters do not give rise to vowel intrusion, while final [ʔk] does. In the Finnish examples in (25b), an /lm/ cluster following the stressed vowel has vowel intrusion, while an /lm/ cluster following an unstressed vowel does not.

- (25) Vowel intrusion and stress
- | | | | |
|------------|--------------|---------------|-------------------------|
| a. Kekchi | kwuʔ'teʔek | 'to howl' | Campbell (1974:270,277) |
| | ʃke:oʔ'ʃkjo: | 'it got cold' | |
| b. Finnish | 'kylymä | 'cold' | Harrikari (1999:15) |
| | 'hedelmä | 'fruit' | |

In the gestural account, this restriction of vowel intrusion to stressed syllables can be explained as a result of the decreased stiffness and decreased gestural overlap that is typical of stressed syllables.

6 Some observations on the distribution of intrusive vowels

While some typological characteristics of intrusive vowels are predicted by research on gestural phasing, a few are not. In the interests of description, this section reviews two such patterns: the fact that intrusive vowels copy only over sonorants and gutturals, and the lack of cross-linguistic restrictions on the syllable positions of consonant clusters with intrusive vowels.

6.1 Copying only over sonorants and gutturals

One unexpected fact that emerges from the present survey is that intrusive copy vowels always copy over a sonorant or a guttural. An intrusive copy vowel in a sonorant-final or guttural-final cluster copies the following vowel, while an intrusive copy vowel in a sonorant-initial or guttural-initial cluster copies the preceding vowel, as shown in (26) and (27) (see Table 1 for references).

- (26) Sonorant / guttural initial clusters: rightwards copying
- | | | |
|-----------------|--|-----------------|
| Chamicuro | jap'leʔeti | 'lightning' |
| Finnish | kalavo | 'transparency' |
| Hausa | k ^w ur ^u k ^w u:tu | 'small drum' |
| Kekchi | paʔat | 'twins' |
| Scots Gaelic | mɔɾɔyan | 'gravel' |
| Tiberian Hebrew | ʃalaħat | 'you (fs) sent' |

(27) Sonorant / guttural final clusters: leftwards copying^a

Hocank	bo:p̄nūs	‘hit at random’
Hua	ok ^u rumaʔ	‘sky’
Lakhota	wag ⁱ miza	‘corn’
Mono	gàfūrū	‘mortar’
Popoluca	it ^a ʔa	‘your father’
Spanish (Chilean)	ing ^a latera	‘England’

^aThe very short intrusive vowels of Lakhota and Spanish are sometimes transcribed schwa, but Albright (1999) and Quilis (1981), respectively, present phonetic evidence that the intrusive vowel’s quality is dependent on the following vowel.

I have found no examples of intrusive vowels copying over non-guttural obstruents. If a language has vowel intrusion in obstruent-obstruent clusters, the intrusive vowel is schwa-like. For example, in the Papuan language Hua (New Guinea), which has intrusive vowels between all consonants in careful speech, the intrusive vowel is a copy vowel only in a C[r] or C[ɣ] cluster, as in (28a). It is a schwa in all other cases, as in (28b) (Haiman 1980). Haiman describes [ɣ] as sonorous and phonetically similar to [r].

(28)	Plain and colored intrusive vowels in Hua	Haiman (1980:26–27)
a.	pot ^a yaie ‘it glanced off’	b. f ^a tu ‘smell’
	ok ^u rumaʔ ‘sky’	k ^a t ^a r ^a guʔ ‘kind of mushroom’
	f ⁱ rie ‘he died’	t ^a v ^a r ^a gie ‘he sharpened it’

It should be emphasised that this restriction to copying over sonorants and gutturals is true only of *intrusive* copy vowels, not of epenthetic copy vowels. In cases where an inserted vowel behaves as syllabic, it is possible for copying to occur over a non-guttural obstruent, as in (29).

(29) Epenthetic vowels copying over obstruents^a

Welsh	/kevn/	→	ke:ven	‘back’
Selayarese	bakri	→	ba:kari	name (loanword)
Kekchi	/k’ox-b’a:nk/	→	k’oxo’b’a:nk	‘to begin’
Mono	/bè/	→	èbè	‘liver’

^aWelsh: Gwenllian (1984); Selayarese: Broselow (1999) quoting Mithun & Basri (1986); Kekchi: Campbell (1974); Mono: Olson (2003)

The restriction of intrusive vowels to copying over sonorants appears to mean, in gestural terms, that a vowel articulation is more likely to heavily overlap the gestures associated with a sonorant than an obstruent. This is not predicted by current research on gestural timing. I point it out here simply as a pattern that has not been previously recognised, and which is in need of explanation.⁹

⁹Incidentally, my survey does not support the tentative suggestion of Browman & Goldstein (1990a:318) that heterosyllabic consonant clusters develop an inserted vowel of fixed quality, while tautosyllabic clusters can develop a copy vowel. Scots Gaelic has copy vowels in heterosyllabic clusters; Dutch has a fixed [ə] in tautosyllabic clusters.

6.2 Vowel intrusion in various syllable positions

Intrusive vowels can occur in a variety of positions within the syllable. Some languages have them only in onsets, some only in codas; some languages have them only in tautosyllabic clusters, some in both tautosyllabic and heterosyllabic clusters. This diversity is unexpected in light of current phonetic research on CC overlap in different syllable positions.

Phonetic studies in several languages have shown that consonant clusters that are in syllable onset position exhibit lower overlap than coda clusters or heterosyllabic clusters. In an electro-palatographic study, Hardcastle (1985) finds less coarticulation, indicating lower overlap, for onset /kɫ/ than /k#l/. Byrd (1996) finds that English onset clusters have a lower degree of overlap than coda clusters. Wright (1996) gives acoustic evidence that word-initial stop-stop sequences have lower overlap than word-internal clusters in Tsou. Chitoran et al. (2002)'s EMMA study of Georgian also finds lower overlap for word-initial than word-internal clusters (of unclear syllabification). This research would lead us to expect that vowel intrusion is more likely to occur in word-initial position than elsewhere, since lower CC overlap has consistently been found in that position.

Surprisingly, this is not the case. Some languages, including Scots Gaelic, Dutch and Moroccan Colloquial Arabic, have vowel intrusion in codas only, as demonstrated in (30).

(30) Onsets vs. codas			
Scots Gaelic	gru:ɡəx	d ^h arag	'dim, red'
	vleħ	d ^h elev	'ground, to warp'
Dutch	prat	harəp	'talk, harp'
	klaxt	mələk	'complaint, milk'
Moroccan Colloquial Arabic	smim ^ə n		'fat (diminutive)'
	nwam ^ə r		'numbers'

If the presence or absence of vowel intrusion indeed reflects the level of gestural overlap within a cluster, the pattern above suggests that at least some codas have lower overlap than onsets in these languages. (For a detailed proposal as to why onsets might exhibit a greater degree of overlap than codas in some languages, see Gafos (2002)'s Optimality Theoretic analysis of this pattern in Moroccan Colloquial Arabic. Briefly, Gafos proposes that onset and coda clusters have the same preferred phasing relationship in Moroccan, but that in onset clusters, the preferred C-C phasing relationship is overruled by demands of the preferred C-V phasing relationship. Since Gafos's theory expresses phasing preferences as rerankable constraints, it predicts that languages could differ in this respect.)

The patterning of vowel intrusion in tautosyllabic versus heterosyllabic clusters is also unexpected in light of phonetic research. Byrd (1996) found no difference between coda clusters and heterosyllabic clusters in English, yet some languages do have vowel intrusion in only one of these cluster types. Some dialects of Dutch

have vowel intrusion only in tautosyllabic clusters, not between syllables, as shown in (31).

- (31) Tauto- and heterosyllabic clusters in Dutch Booij (1995:127–8)
- | | | | |
|---------|-----------|-------|---------|
| vɛr.kən | ‘to work’ | vɛrək | ‘work’ |
| tyl.pən | ‘tulips’ | tyləp | ‘tulip’ |
| pol.ka | ‘polka’ | mɛlək | ‘milk’ |

Hocank has longer intrusive vowels within syllables than between syllables. Intrusive copy vowels with relatively long durations appear in CR onset clusters, as in [k̄ānāk] ‘marry’, while intervocalic heteromorphemic CR clusters, which arguably are heterosyllabic, have only short schwa-like intrusive vowels, as in [wanīg^ənīk] ‘little bird’ (Miner 1992:31). Finally, in some languages syllable division has no effect on vowel intrusion. In Scots Gaelic, the same RC clusters have vowel intrusion whether they form a coda, as in [ʔɔrək] ‘to seek’, or a heterosyllabic cluster, as in [marəkəy] ‘market’ (Borgstrøm 1940:212). I have found no universal pattern as to whether onset, coda, or heterosyllabic clusters favor vowel intrusion most. This conflicts with the picture that emerges from the experimental studies cited above, where overlap seemed to be consistently lower in onset clusters.

Given that phasing patterns within the syllable have been instrumentally studied in only a few languages, the clash between the typological conclusions drawn from these studies and the typological characteristics of intrusive vowels do not necessarily disprove the gestural analysis of vowel intrusion. It should be noted that generalisations like “onsets have less overlap than codas”, being empirical observations, are not inherent to gestural approaches; they are descriptions of known data which hold only as long as counterexamples are not discovered. (An example of a principle that *is* inherent to the gestural approach is “heterorganic clusters are more likely to contain an acoustic release”. This generalisation follows from language-independent facts about task dynamics, so it would be truly problematic for the gestural account if vowel intrusion occurred more often in homorganic clusters). For now, the issue of gestural phasing within the syllable should be acknowledged as an area that does not lend support to the gestural analysis of vowel intrusion, but does not necessarily weaken it either.

7 Effects of vowel intrusion on consonants

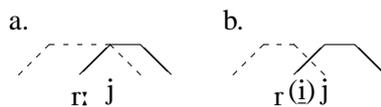
7.1 Interaction of gestural effects

I have argued that an intrusive vowel is not a segment or a syllable nucleus, and hence will not affect any phonological pattern that refers to segments or syllables. However, this does not mean that an intrusive vowel is irrelevant to all other sound patterns. A gestural effect like vowel intrusion can interact with other gestural effects, such as allophonic variation in consonants. For this reason, an intrusive vowel may sometimes be described as ‘conditioning’ a change in an adjacent consonant.

In gestural approaches, allophonic variation is analysed as an effect of gestural phasing. Some types of consonant allophony are caused by overlap between the gestures associated with adjacent segments. For example, in a /sj/ sequence, overlap between the oral gestures of [s] and [j] will cause the [s] to become palatalised and sound more like [ʃ] (Zsiga 1995; Cho 1998). Allophonic variation can also result from different timings of the gestures that make up a segment. For example, the difference between aspirated and unaspirated stops in English is in the relative timing of the laryngeal opening gesture and the oral closure gesture.

Since vowel intrusion and consonant allophony both depend on gestural phasing, they can interact if they happen to involve the same gestures. A single change in the gestural score may create an intrusive vowel while also changing the realisation of a consonant. A possible example of this is seen in Saami, where vowel intrusion occurs between a geminate sonorant and a heterorganic consonant. Vowel intrusion is associated with optional degemination of a preceding sonorant, so that /kir:ʃii/ ‘book, nom. sg.’ can be pronounced [kir:ijii] or [kirijii] (Bye 2001:166). This degemination does not happen before lexical short vowels; it is only associated with vowel intrusion. This suggests that it may be a gestural effect itself. In fact, it is possible to model both degemination and vowel intrusion as a single change to the gestural score: both can be produced by ending the sonorant gesture early. In (32a), a geminate [r:] overlaps the following [j] to the extent that there is no release between the two consonants. In (32b), the [r] has been shortened by moving its release and offset, without moving its onset. This shortening also reduces the level of overlap between [r] and [j], causing an intrusive vowel to be heard between them. Note that the overall duration of the consonant cluster is retained, even as there is variation in the internal timing.

(32) Degemination and vowel intrusion in Saami



In this way, a single change in timing can result in both a shorter [r] and vowel intrusion. However, it would not be quite correct to say that the intrusive schwa conditions the degemination or vice-versa. Both are acoustic byproducts of a single articulatory reorganisation of the consonant cluster. This allows us to explain why vowel intrusion shows a correlation with a type of consonant variation, while at the same time being phonologically invisible for most purposes.

Crucially, vowel intrusion should only ‘condition’ processes that are directly related to it, in the sense of involving the same gestures. If a pattern of consonant allophony is triggered only by a vowel gesture, then an intrusive vowel should not trigger it. Tiberian Hebrew provides an example of this. In Hebrew, non-geminate stops are spirantised in postvocalic position, as in (33) (McCarthy 1979). Spirantisation happens after underlying vowels (a), vowel derived from consonants (b), and epenthetic vowels (c) alike. The only vowel that does not trigger spirantisation is a vowel that I analyse as intrusive (d): a copy vowel that is inserted in final

GC clusters, where G is a guttural. In this case only, the apparently postvocalic consonant remains a stop.

- (33) Tiberian Hebrew spirantisation (as realised on the 2fs suffix)
- a. /katab + t/ → kaθavt ‘you f.s. wrote’
 - b. /galj + t/ → galiθ ‘you fs. went into exile’
 - c. /kelb/ → kelev ‘dog’
 - d. /jalaħ + t/ → jalahaṯ ‘you f.s. sent’

This exception can be explained in the gestural account: if the copy vowel in (33c) is intrusive, then the [t] is not really postvocalic. It is the second consonant in a cluster, and hence in a position where spirantisation is not expected. I assume that spirantisation occurs due to the difficulty of moving quickly from a highly open vocal tract position, as in a vowel articulation, to a complete closure. In the first stop following a vowel, the closure is not fully achieved. But the intrusive vowel is not a full vowel gesture; it is only an acoustic release coloured by the tail end of the preceding vowel’s gesture. Hence, a consonant following an intrusive vowel does not spirantise.

Saami and Tiberian Hebrew demonstrate that the relation between vowel intrusion and consonant allophony is more complicated than that between vowel intrusion and categorical processes like stress. An intrusive vowel should never be relevant for categorical processes, but it may show a correlation with other phonetic patterns. In this sense, the intrusive vowel may seem to be ‘visible’ for a limited range of phenomena.

8 Historic change from intrusive to syllabic

Vowel intrusion is a phonetic, gestural phenomenon that does not affect the segmental or syllabic structure of a word. However, like other phonetic processes, it may become phonologised. A vowel sound that originated as intrusive may be re-analysed over time as a segmental vowel, either epenthetic or underlying (Steriade 1990, Browman & Goldstein 1990a:318, Browman & Goldstein 1992:53, Jetchev 1995). In (34) are some historical cases of vowel insertion that resemble vowel intrusion in conditioning environment and vowel quality.

- (34) Historical epenthesis that may have begun as vowel intrusion^a
- | | | | | | |
|----------------------|-----|-----------------|---|----------------------|-------------|
| Irish Gaelic | | gorm | > | 'gor _ə m | ‘blue’ |
| Late Latin | | <i>scriptum</i> | > | <i>sc̄rīptum</i> | ‘a writing’ |
| Negev Bedouin Arabic | | qahwa | > | ga'h _ə wa | ‘coffee’ |
| Oscan | I. | <i>Mulcius</i> | > | <i>Múlúkiis</i> | name |
| | II. | <i>patri</i> | > | <i>patereí</i> | ‘father’ |
| Sardinian | | umbra | > | umbara | ‘shadow’ |

^aSources: Irish: Ó Siadhail (1989); Latin: Schuchardt (1867:vol.3:421); Negev Bedouin Arabic: Blanc (1970); Oscan: Buck (1904); Sardinian: Wagner (1907)

Sometimes intrusive vowels in one dialect of a language correspond to segmental vowels in another dialect. Engstrand (1987) reports that speakers of Lule Saami consider the vowels inserted in R:C clusters to be syllabic, in contrast to speakers of other Saami dialects. Harms (1976) argues that vowels which were once intrusive are now segments in northern dialects of Finnish. Syllables with intrusive vowels have collapsed with disyllables in Irish Gaelic (Greene 1952:217), and apparently in the East Sutherland dialect of Scots Gaelic (Dorian 1965, Ternes 1973:102). Booij (1995:128) suggests that there are southern and western dialects of Dutch that have made intrusive schwa underlying.

The ‘segmentalisation’ (Harms 1976) of intrusive vowels is likely a case of listener-initiated sound change (Ohala 1981). If intrusive vowels become too acoustically similar to segmental vowels, speakers may reanalyze them as segments (Browman & Goldstein 1990a:318). This results in cases of segmental vowels that have some properties similar to intrusive vowels, in terms of conditioning environment, quality, and invisibility for some (usually fossilised) phonological patterns. However, when an intrusive vowel is segmentalised, it can lose the typical characteristics of intrusive vowels described in (2). As Hyman (2001:153) observes, a phonologised pattern becomes subject to ‘structural or systemic principles’ that can make it different from its phonetic predecessor.

For example, the vowel may no longer be restricted to copying over sonorants. An example of this change is found in Finnish. Harms (1976) points out that in some northern and eastern dialects of Finnish, originally intrusive vowels now count as a syllables for alternating stress, as in [‘kel_əkasta] ‘from the sled’. This indicates that the vowels have been reanalyzed as segments. Strikingly, in one such dialect (Lapua) the direction of vowel copy has apparently reversed. In the examples in (35), the historically added vowel now copies the quality of the following vowel, even if this involves copying over an obstruent.

(35)	Standard	Lapua	
	kelkka	kelakka	‘sled’
	velho	veloho	(no gloss)
	ilma	ilama	‘air’

Synchronically intrusive vowels, by contrast, only copy over a sonorant or guttural, as shown in (26) and (27). Harms suggests that the Lapua vowels changed quality so that the words would better resemble the existing inventory of three-syllable stem types in Finnish. It is not surprising that an intrusive vowel might change quality at the same time that it becomes syllabic. Once the vowel has its own gesture, its quality is no longer determined by purely phonetic considerations, and can be influenced by other characteristics of the grammar.

Another example of phonologised intrusive vowels comes from Bedouin and Gulf dialects of Arabic. A copy vowel appears in sequences of [aGC], where G is a guttural. In terms of vowel quality and conditioning environment, this vowel insertion fits the vowel intrusion syndrome, and it may still be a gestural effect in some dialects. But in other dialects, such as Negev Bedouin, the inserted [a] is

now clearly syllabic. It counts for stress, which usually falls on the second syllable, as in [da'xanah] 'smoke'. Along with the onset of syllabic behavior, the vowel is also losing its copied quality. The preceding vowel is now optionally subject to the process of open syllable raising, so that 'month' can be pronounced [ja'har^v] or [ʃi'har^v] (Blanc 1970:126). This shows not only that the first [a] is now in an open syllable, but that the two vowels have separate gestures. True intrusive copy vowels must undergo segmental changes in tandem with the vowels they copy (see examples (14, 17)), because they share a gesture.

Phonologisation is not an inevitable fate for intrusive vowels, nor does it happen automatically upon their reaching some threshold of phonetic duration. Scots Gaelic and Hocank have rather long intrusive vowels that still behave as non-segmental. It is likely that the ability of intrusive vowels to resist reanalysis depends on how much the phonetic realisation of disyllables differs from syllables with intrusive vowels. In Hocank and Scots Gaelic, the two sequence types are noted to sound very different in pitch and timing, and this may help speakers to keep them distinct.

9 Conclusion

I have argued that there are two ways a vowel sound can be inserted in a word. In vowel epenthesis, a vowel segment is added, along with a vocalic gesture, and this segment forms the nucleus of a new syllable. In vowel intrusion, the articulatory gestures associated with existing segments are phased in a way that creates an acoustically vocalic period, but no phonological segment is inserted, and hence no new syllable is created. The primary diagnostic for distinguishing intrusive vowels from epenthetic vowels is to check whether the vowel behaves as a syllable nucleus, both for phonology and for speaker intuitions.

The difference between epenthesis and intrusion can be captured in a representational framework that includes both a gestural component and traditional segments and syllables. Vowel intrusion is purely a phenomenon of the gestural layer, while vowel epenthesis involves a change to the segmental string. While the gestural representation is adapted from Articulatory Phonology, I argue that the constraints which classic Articulatory Phonology places on derivation are too strong. To model epenthesis, it is necessary to allow insertion of gestures.

A cross-linguistic survey finds that intrusive vowels in different languages have characteristics in common. They come in a restricted range of qualities, they occur mostly in heterorganic consonant clusters, and they often disappear in fast speech. Intrusive copy vowels only copy over sonorants and gutturals, unlike epenthetic copy vowels. Several aspects of this typology fall out of independently motivated properties of gestural phonology. Others are currently unexplained, but may indicate fruitful areas for future instrumental studies.

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