THE PHONOLOGY AND PHONETICS
OF NASAL OBSTRUENT SEQUENCES

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This dissertation explores the relationship between the phonological patterning of nasal-obstruent sequences (NC sequences) and their phonetic realizations. I argue that there are distinct NC patterns in the phonology, specifically unary segments (such as prenasalized stops) vs. clusters, and that these patterns are reflected in the phonetics. The data for these investigations come primarily from phonological and phonetic studies (both acoustic and aerodynamic) collected through fieldwork on four Austronesian languages—Tamambo and Erromangan of Vanuatu, and Pamona and Manado Malay of Indonesia.

Clear cases of prenasalized stops, in languages like Fijian, and clusters, in languages like English, provide ample evidence for different phonological NC entities, despite the fact that some languages are more difficult to classify. I propose a methodology for determining the status of an NC, which separates the often-conflated issues of tautosyllabicity and unary segmenthood. Grouping NC-types along two principle divisions—unary vs. cluster, and voiced vs. voiceless obstruent—I argue that only six of sixteen possible patterns (combining 0-4 NC types) are attested. The unattested cases are attributed to two factors: the lack of prenasalized voiceless stops, and the lack of contrasting unary vs. cluster NCs of the same voicing specification. An investigation of phonetic properties of NC sequences, including total NC duration, duration of a preceding vowel, and degree of nasalization in a

preceding vowel, reveals that total duration does correlate with phonological NC structure while the other two factors do not. Data on the relative nasal-oral timing of NC sequences reveals interesting similarities across the types: voiced NC sequences, NC sequences with a voiceless stop, and NC affricates each have distinct realizations, regardless of phonological status.

Not only are phonological NC patterns reflected in the phonetics, but the phonetic realizations also have important consequences for the phonology. The phonetic characteristics of unary vs. cluster NCs—both their differences and similarities—are argued to explain gaps in the phonological patterns. Phonological representations of NCs are proposed that crucially include both prosodic and segmental structure, as well as being consistent with the phonetic facts. These representations have implications for other reported types of partially nasal segments.

BIOGRAPHICAL SKETCH

Anastasia Riehl was born in Cedar Rapids, Iowa in 1971 to Kay and Richard Riehl, and graduated from George Washington Senior High School in Cedar Rapids in 1989. She received a bachelor's degree in English, summa cum laude, from the University of Iowa in 1993, and a master's degree in linguistics from the same institution in 1996. She entered the graduate program in linguistics at Cornell University in 1999. In 2003, she was awarded a fellowship from the Fulbright Hayes Doctoral Dissertation Research Abroad Program to undertake fieldwork in Indonesia and Vanuatu.

This book is dedicated to my speakers.
Thank you for sharing your language and friendship.

Buku ini saya dedikasikan pada penutur-penutur
asli yang memberi masukan pada saya.
Terima kasih banyak sudah membagi pengetahuan bahasa
dan pertemanan yang tidak akan pernah saya lupakan.

Mi dediketem buk ia i go long olgeta we oli givhan long mi,
mo oli serem lanwis blong olgeta.
Tank yu tumas long gudfala hat blong yufala evriwan.

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I was first introduced to linguistics as an undergraduate at the University of Iowa, where I later returned to pursue a master's degree in the subject. I am thankful to many in that department for a positive experience and one that motivated me to continue on in the field. I am especially grateful to Abigail Kaun, an inspirational teacher and good friend, for first getting me excited about phonology. I am also grateful for the guidance of Alice Davison, Jerzy Rubach, and Cheryl Zoll, and for the camaraderie of my fellow grad students, especially Oduntan Bode, Holly Gray, Catharine Schaff-Stump, and Karen Wood.

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CHAPTER ONE:
THE PHONOLOGY OF NASAL-OBSTRUENT SEQUENCES

1.1 Introduction

The topic of this thesis is the phonological structure and phonetic realization of nasal-obstruent consonant sequences (NC sequences). NC sequences have generated great interest among phonologists for decades, raising a number of important questions. *What do NC patterns tell us about a language's phonemic inventory or syllable structure? How should the sequences be represented? What phonetic characteristics define them?* Despite the dozens, if not hundreds, of pages devoted to such issues over the decades, the answers to many of our questions about NC sequences remain somewhat elusive.

Why are NC sequences so interesting? The reason lies in their varied configurations. While in some languages, such as English, the nasal and the obstruent are widely assumed to function as a cluster, in other languages, such as Fijian, the two parts instead behave like a single unit segment, in this case a prenasalized stop. On their own, the NC clusters in a language like English are not particularly noteworthy. After all, a single phone generally composes a single segment, and therefore the fact that this sequence of two sounds forms two segments falls in line with our expectations. The unary NC segments in Fijian, however, defy expectation by allowing two sounds to function as if they were one unit. That Fijian NC sequences suggest the existence of such a pattern underlies part of our interest in NC sequences. That NC sequences behave like single segments only in *some languages*, such as

Fijian, but behave like clusters in *other languages*, such as English, underlies the other aspect of our interest.

Having two different patterns for the same apparent sequence of phonetic entities challenges our assumptions about phonology and phonetics. If the mapping from contrastive element to phone is not necessarily a one-to-one mapping, what does this tell us about the structure of segments? This question, part of the larger discussion about the relationship between quality and quantity, has been at the forefront of NC discussions for decades (e.g. Anderson 1976). More recently, discussions of NCs have turned to the sequences' phonetic characteristics: if NC sequences have different phonological patterns in different languages, do they also have different phonetic realizations, and what does the answer suggest about the nature of the phonology-phonetics interface? Before delving into these questions, let us consider in a bit more detail the cases of English and Fijian mentioned above.

The NC sequences in English are uncontroversially considered clusters. In short, they pattern like other clusters in the language, so there is no reason to believe that they are anything else. First, like other clusters, NC sequences only occur in environments where they do not violate sonority. (Sonority will be discussed in more detail in section 1.3.1.) For example, as illustrated in (1.1), NC sequences, such as /mp/, along with other sequences of a more sonorous sound followed by a less sonorous sound, such as /lt/, can occur word-finally where they decrease in sonority or can occur word-medially where the two sounds are assumed to be in separate syllables and therefore not subject to sonority; they cannot, however, occur word-initially where they would incur a violation of sonority. Sequences like /dr/, on the other hand, where a less sonorous sound precedes a more sonorous sound, occur in the mirror image of environments: word-finally they do not occur, and word-initially and medially they are assumed to form the onset of a syllable.

(1.1)

initial	medial	final
***lt**-	mo**lt**en	resu**lt**
***mp**-	te**mp**o	enca**mp**
dragon	a**dr**ift	*-**dr**

Second, NC sequences can occur across morpheme boundaries in English, for example, *un+tenable*, *im+precise*. It is therefore clear that at least some NC sequences in English are clusters of two segments. While monomorphemic forms, such as *amber* or *anger*, cannot be divided morphologically in English, there is no evidence that they require a different characterization, as far as segmental composition is concerned, than the bimorphemic sequences. Symmetry and economy therefore suggest that all NCs in English are clusters. Third, the nasal and obstruent portions of an NC sequence can both occur independently, that is, /n/ and /d/ are both found in lexical items, as are /nd/ and /dn/, and it is not the case that the presence of one predicts the presence of the other. While this independence may not necessitate a cluster analysis, it is fully consistent with one, and it stands in contrast to languages with clear prenasalized stops, as will be seen in Fijian.

Fijian (Schütz 1985) is frequently cited as a language with clear prenasalized stops. In short, the NC sequences in Fijian have the patterning of single segments. First, the entire series of voiced stops (as well as the voiced trill) always occur with a preceding nasal component; that is, [b] never occurs alone, but only as [^{m}b]. The voiceless stops, on the other hand, never occur with a preceding nasal. Below are examples of each stop in initial and medial position (words are from Capell's 1973 dictionary):

(1.2)

	initial	medial	non-occurring
[^{m}b]	[**^{m}b**onu] 't.o. eel'	[so**^{m}b**u] 'down'	[#b-], [-b-]
[^{n}d]	[**^{n}d**evo] 't.o. stone'	[vu**^{n}d**i] 'banana'	[#d-], [-d-]
[^{ŋ}g]	[**^{ŋ}g**one] 'child'	[u**^{ŋ}g**a] 'hermit crab'	[#g-], [-g-]
[t]	[**t**ovu] 't.o. shell'	[ma**t**e] 'death'	[#nt-], [-nt-]
[k]	[**k**alu] 'to whistle'	[wa**k**i] 'to mix'	[#ŋk-], [-ŋk-]

Second, the NC sequences occur word-initially where generally only single segments can occur, adding to the evidence that the two parts form one unit. Third, there are no final consonants in the language, and there are no medial consonant sequences other than NC, suggesting that the language only allows open syllables. For these reasons, Fijian NC sequences uncontroversially receive a unary analysis: the NCs are essentially the voiced stop series, articulated with a preceding nasal component.

With these examples of English and Fijian, we can conclude that there do seem to be clear cases of languages with unary NC segments and those with NC clusters. The following figure represents English and Fijian on opposite ends of an NC spectrum. As will be seen later in the chapter, however, while these endpoints are clear, the position of other languages is less so, and such a spectrum is an oversimplification of the facts.

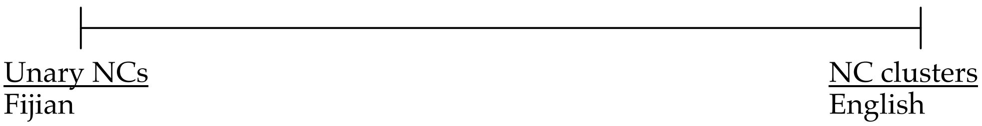

Figure 1.1: Simple schematization of an NC spectrum

Given that there are different types of NC sequences cross-linguistically, one challenge for phonology is how to capture this difference. This issue has been of great interest to post-*Sound Pattern of English* phonology (Chomsky and Halle 1968). In fact, the existence of segments composed of more than one phonetic entity, such as prenasalized stops, was one of the central factors that led to a move away from uniform feature matrix representations of segments to those that separate quality from quantity. Various models have been posited to account for the fact that a sequence of the same two sounds can behave as either one or two units. Specific proposals for the structure of prenasalized stops (such as Anderson 1976, Sagey 1986, Clements 1987, Pigott 1988, Rosenthall 1988, Steriade 1993, Trigo 1993, and van de Weijer 1996) will be discussed in section 1.5. In descriptive terms, the difference can be illustrated as in the following figure, where the circles represent root nodes, or in some approaches timing units. (I assume root nodes here, without getting into the substance of different proposals at this point.)

NC cluster
English [nd]

prenasalized stop
Fijian [^{n}d]

Figure 1.2: Descriptive representations of NC clusters and prenasalized stops

In an NC cluster, the nasal and obstruent portions, residing on a featural tier (following terminology by Broselow 1995)—one related to *quality* of the sounds, each link to a separate node on a segmental tier—one related to the *quantity* of the segments; in a prenasalized stop, however, the same two entities on the featural tier link to a single root node on the segmental tier. A few other consonant sequences, such as /tʃ/, appear to pattern as two segments in some languages and one segment in others. A third possibility, that one phone links to two root nodes, is witnessed in other sound sequences, such as geminates. (See Broselow 1995 and references therein for a broader overview of these issues.) The representations of NC will be discussed in more detail in section 1.5.

More recently, phonologists are increasingly interested in how phonetic detail relates to phonological structure. NC sequences are crucial to these discussions as well. We might expect, given that /nd/ and /ⁿd/ are understood to have different phonological structures, that the sequences would have different phonetic properties. It had long been assumed that they do differ, specifically that a cluster is longer than a unary segment. In Herbert's (1986) monograph on prenasalized segments, for example, shorter duration is one of his defining criteria for a prenasalized stop:

> A prenasalized consonant is formally defined as a necessarily homorganic sequence of nasal and non-nasal consonantal segments which together exhibit the approximate surface duration of 'simple' consonants in those language systems within which they function. (10)

More recent studies, however, that incorporate phonetic data, challenge these long-held impressionistic observations. Articles by Browman and Goldstein (1986), Maddieson and Ladefoged (1993), and others, have been interpreted to suggest that there is in fact no distinct phonetic difference between NC clusters and prenasalized stops, leading to an often-stated current view in the literature, such as that expressed by Downing (2005), that

“There is no consistent phonetic contrast, like a durational distinction, between prenasalized segments and NC clusters” (183). However, I will argue, based upon the phonological and phonetic data in this thesis, that the past studies in this area reached premature and incorrect conclusions, the fault of insufficient data and questionable phonological assumptions, and that earlier intuitions that the sequence-types do differ phonetically is well supported.

The primary question investigated in this thesis is the following. *Are there distinct NC patterns in the phonology, and if so, are these patterns reflected in the phonetics?* I have already begun to answer the first part of this question with the introductory illustrations of English and Fijian and will continue with this discussion for the rest of this chapter, as well as in chapter 2 where I present a classification of NC-type combinations and phonological NC analyses of several languages. The ultimate answer to this part of the question is *yes*, although as will be seen, the issue is more complicated than the straightforward cases of English and Fijian might imply. The second part of the question, that relating to the phonetic realization of NC sequences, will be addressed in chapters 3 through 6. I will demonstrate, with an untangling of contradictory and insufficient past studies, combined with new phonetic data, that the answer to this part of the question is also *yes*, that different phonological patterns indeed have different phonetic realizations. Specifically, I will demonstrate that unary NC segments have duration equivalent to other comparable single segments in a language while NC clusters are substantially longer in duration than comparable single segments.

The languages discussed in this thesis are primarily (although not exclusively) from the Austronesian family. I focus on these languages as members of this family reflect the range of NC sequence-types observed cross-linguistically. In order to bring to bear sufficient phonological and phonetic data, I conducted fieldwork on four Austronesian languages for this study, Pamona and Manado Malay in Indonesia, and Tamambo and Erromangan in Vanuatu. These four languages will be the focus of analysis throughout most of the thesis. The generalizations that arise are predicted to hold cross-linguistically. However, it is certainly possible that additional data, particularly from other families, will challenge some of the conclusions, and regardless, a fuller investigation of other groups—such as Bantu, known for its interesting NC sequences—would be of benefit to the discussion. Additionally, I limit my discussion primarily to NC stops and affricates (as opposed to other manners of articulation) and to NC sequences (rather than CN sequences), as these are the most relevant to the present discussion; however, I will touch briefly upon some of these other categories in chapter 6, section 6.5.3.

Before continuing with the main substance of chapter 1, it is useful to provide a few definitions of the terms and symbols that will be used regularly throughout the thesis.

- *NC sequence*: Any sequence of homorganic nasal and obstruent elements, regardless of phonological status
- *NC cluster*: Any sequence of homorganic nasal and obstruent elements that forms two phonological segments; represented, for example, as /nd/
- *Unary NC segment/prenasalized stop*: Any sequence of nasal and obstruent elements that forms one phonological segment; represented, for example, as /^{n}d/
- *Voiced NC or NÇ̬*: An NC sequence where both the nasal and obstruent portions are voiced [read as: “nasal, voiced consonant”]
- *NÇ̥*: An NC sequence where the nasal portion is voiced but the obstruent portion is voiceless [read as: “nasal, voiceless consonant”]

It is important to draw particular attention to the first term in the list: *NC sequence*. I use this term very generally to refer to any NC sequence, regardless of whether it forms a unary segment or a cluster. There does not appear to be an ideal term for this broad usage, nor one used consistently in the literature, so I adopt the term "sequence". When I want to refer to the phonological structure of particular NCs, I will use the terms *unary* and *cluster*.

The remainder of this chapter is organized as follows. In section 1.2, I continue the discussion of whether or not NC clusters and prenasalized stops are distinct phonological entities. In section 1.3, I present a methodology for analyzing phonological NC status. In section 1.4, I discuss the role of voicing in NC sequences. In section 1.5, I consider the issue of phonological representations. In section 1.6, I summarize the chapter, and in section 1.7, I outline the structure of the remainder of the thesis.

1.2 The unary-cluster NC distinction

The first part of the research question under investigation in this thesis is: *Are there distinct NC patterns in the phonology?* More specifically, is there evidence that some NC sequences pattern as single segments, while others pattern as a cluster of two segments? I would argue that this question has already been answered through the discussion of the English and Fijian cases. While the issue is certainly more nuanced and complex than we have yet seen, and while many languages will be much more difficult to classify, the existence of even these two clear cases is enough to determine that different phonological NC patterns are possible. This conclusion will continue to be justified throughout this chapter and throughout the dissertation, as data from a number of languages are considered.

On the other hand, Herbert (1986) (hereafter “Herbert”) completed an extensive study of the markedness of prenasalized stops, the most detailed discussion of such sounds to date, in which he claims that all NC sequences are clusters. Herbert argues persuasively in many cases that NC sequences frequently characterized as unary are in fact clusters. However, his claims are motivated by theoretical assumptions that these marked segment-types are not possible underlyingly, and he then generates surface prenasalized stops from underlying clusters through a complex rule of unification.

Even from such an extreme view on the non-existence of prenasalized stops, however, there appear to be indisputable cases where the two phones indeed constitute a single phonological entity. Herbert’s analysis essentially excludes those languages with arguably the clearest cases of unary NC segments—those where the voiced series of stops is prenasalized and no plain voiced stops exist. His examples are from the Reef Islands-Santa Cruz Family, but this is a common phenomenon throughout Oceania, including of course Fijian (and is seen elsewhere as well). Herbert claims that these stops are simple voiced stops in the phonology, which happen to be articulated with prenasalization. While this may be a reasonable characterization and the issue may come down to one of theoretical perspective and terminology, these segments are key to the discussion of NC sequence structure, given that they are undeniably unary segments (so undeniable that Herbert excludes them from a study that argues all NC sequences are clusters).

In order to claim that there is a phonological difference between unary and cluster NC sequences, it is necessary to consider what factors might distinguish one type from the other. In the next section, I discuss a general methodological approach to analyzing the NC sequences in a language. I demonstrate that there is a phonological distinction between unary and cluster NC sequences, evidenced by many clear and undisputed cases in the literature. As will be explored in detail in later discussion, however, no single language contrasts the two types; therefore, the issue is not one of phonological *contrast* but of a phonological *distinction* between two different phonological entities.

1.3 Determining phonological NC status

In the introductory sketches of English and Fijian, the determination of whether an NC sequence forms a cluster or a unary segment is presented as fairly straightforward. However, in many languages, the evidence is less clear-cut, and the lack of consistent, cross-linguistic diagnostics makes the task all the more challenging. Ladefoged (1968) (as quoted by Herbert) alludes to the dilemma when he states "The decision as to whether to regard the members of a particular sequence of consonants as single phonemic units, or as clusters, is, of course, often arbitrary" (1). This quote hints at one of the primary points of confusion in past NC studies exploring the relationship between phonology and phonetics: the phonological analyses may be based on a lack of clear evidence. If the assumed phonological structure of an NC sequence is incorrect, then this may lead to confusion in relating the phonology to the phonetic characteristics.

Although the status of NCs may be difficult to determine in some languages, in other languages it is straightforward, and the result is ample cross-linguistic evidence for the existence of distinct NC patterns. One of the goals of this study is to identify clear cases of cluster languages and clear cases of unary languages, and to use the phonological and phonetic data from these languages to address the larger questions of the thesis. In this section, I begin by reviewing some of the factors commonly taken into account when making a determination of phonological NC status. Then in section 1.3.1, I propose a methodology for undertaking such an analysis, which involves considering the separability of the NC components, the syllable structure of the sequences, and other types of evidence for segmenthood. An important difference between the approach offered here and that often taken in past studies, is that tautosyllabic sequences do not necessarily entail a unary analysis, a point to be discussed in more detail below.

In his aforementioned monograph on prenasalized stops, Herbert cites the three most common considerations in determining the phonological status of an NC: (1) timing, (2) sonority, and (3) syllable structure. The first of these, timing, is phonetic in nature, and as such will be set aside for now. The task of this thesis is to determine whether or not phonological patterns are in fact reflected in the phonetics. (Herbert makes the assumption that all surface prenasalized stops have duration comparable to a single segment). Therefore, using phonetic data to argue for phonological status is not warranted at this stage of the discussion (although a relationship between phonological structure and phonetic timing is indeed found, as argued throughout the following chapters). The related second and third considerations—sonority and syllable structure—are indeed relevant to analyzing phonological NC status and will be discussed in section 1.3.1, but they are only part of the story, as will be seen below. An additional factor cited by Herbert, relating to the separability of the two parts of a sequence, is quite critical: there seems to be a fairly strong consensus that if the nasal and oral portions are indivisible (if one or both cannot occur independently), the sequence must form a unary phoneme.

While there are numerous factors that linguists consider in making a determination of NC sequence status, there appear to be few, if any, universal criteria; rather, the task is necessarily language specific. Before proceeding with the approach sketched in the following section, I want to dispense with a few factors that will not be used as criteria in this model, but which should be mentioned as they surface in other NC discussions: homorganicity of the NC parts, morphological structure of the NC, and underlying versus derived unary segments.

First, homorganicity of the parts, often mentioned in NC studies, is not necessarily a factor in considering NC structure. As discussed by Herbert as well as Maddieson and Ladefoged (1993), while the elements in a unary NC must be homorganic, homorganicity does not necessarily entail a unary analysis (it is a necessary, but not a sufficient, condition). In many languages, all monomorphemic NC sequences must be homorganic, even when they form clear clusters, such as in English. The extremely common cross-linguistic rule of nasal assimilation before obstruents is argued by Ohala (1990) to be attributable to the difficulty of perceiving nasal place features in this environment (see also Malecot 1956, Ohala and Ohala 1993). In this study, all NCs under consideration are homorganic, and I do not consider this homorganicity an indicator of unary segmenthood.

Second, I do not consider morphological structure when discussing the status of an NC. This is not to say that morphological facts are not sometimes useful in seeking an full understanding of NC behavior in a language. As the informal discussion of English in the introduction illustrates, if clear word-internal bimorphemic clusters pattern in the same way as monomorphemic sequences, this might be viewed as *corroborating* evidence that the monomorphemic sequences are also clusters. However, such information alone does not necessarily provide clear answers to NC status. Although one might argue that a bimorphemic NC sequence could not form a true prenasalized stop due to the fact that it must be an underlying cluster, it is not clear that this is necessarily actually the case. In a number of languages, a prefix consisting simply of nasalization will be realized differently depending upon the character of the initial segment. A nasal prefix may form a tautosyllabic sequence before a voiced stop, but surface as syllabic before a voiceless stop or delete altogether, which may be interpreted as offering evidence for prenasalized voiced stops. This is not to say that the voiced sequences in such cases necessarily form unary segments (and it is worth pointing out that vast majority of bimorphemic cases are clearly not unary segments), but it is to say that there is no a priori reason why the morpheme boundary would prohibit this. After all, there are other cases where features of two separate morphemes coalesce into a single segment, as in the nasal substitution process discussed in section 1.4.

Finally, I do not explore the issue of underlying versus derived prenasalized stops. This issue, which is at the core of Herbert's monograph, was very much driven by the theoretical assumptions of the time. I do not discuss whether such analyses are justified. Rather, I assume that the underlying and surface phonological structures, at least for the cases under consideration in this thesis, are the same.

1.3.1 An approach to the phonological analysis of NC sequences

I approach the determination of NC phonological status through a three-step process, as schematized in the flow chart in figure 1.3.

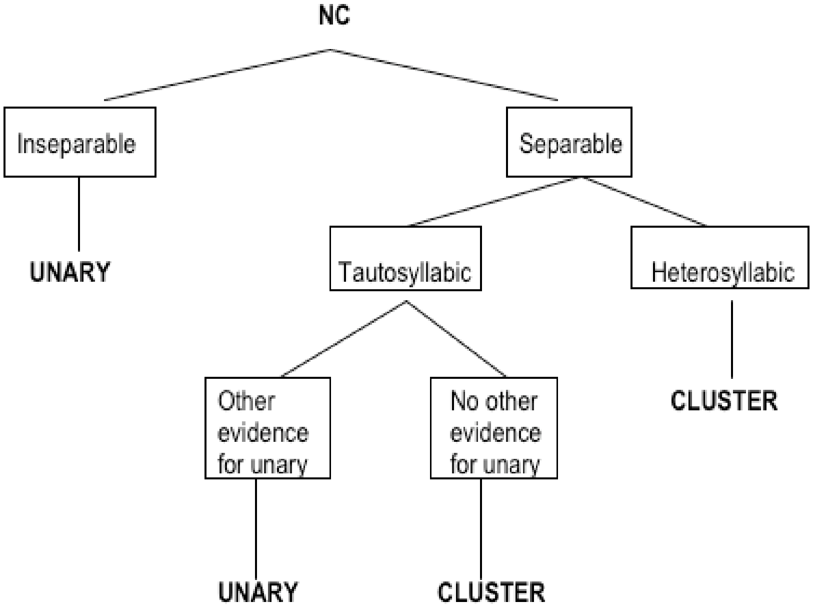

Figure 1.3: Schematization of three-step approach to determining phonological NC sequence status

An overview of the approach is as follows. The first step is to identify whether or not the NC components are inseparable or separable. If inseparable, the sequence is unary; if separable, more evidence is needed. The second step is to identify whether or not the separable sequence is heterosyllabic or tautosyllabic. If heterosyllabic, the sequence is a cluster, if tautosyllabic, more evidence is needed. The third step is to identify whether or not there is additional evidence that the separable tautosyllabic sequence forms a unary segment. If there is such evidence, the sequence is unary, if not the sequence is a cluster. This final step constitutes a critical and often overlooked step in the analysis. Ultimately, the result is two paths to unary segmenthood and two paths to clusterhood. The inseparable unary sequences on the leftmost branch, and the heterosyllabic clusters on the rightmost branch, form the clear and uncontroversial classes. The tautosyllabic groups in the middle encompass the less clear cases, and those that have likely caused confusion in past analyses. Each of these steps is discussed in more detail below.

Step one: separable or inseparable?

The first step is to determine whether or not the components of the NC sequence are separable. The inseparability of the components is often viewed as strong evidence for a unary analysis. If a particular phonetic entity does not occur independently but forms an indivisible unit with another sound in a predictable manner, then those sounds are understood to form a single phoneme. As mentioned earlier in the chapter, even Herbert, who argues that all underlying NC sequences are clusters, exempts this category of NC sequences from his analysis, claiming that such sequences are simply underlying voiced stops whose phonetic realization involves nasalization. In other words, even from the perspective of one who disputes the existence of underlying unary NC segments, these prenasalized stops cannot be considered anything other than single segments.

The non-independently occurring part of a prenasalized stop is always the oral portion, which is hardly surprising given that the vast majority of the world's languages have plain nasals (Ferguson 1963).[1] For most languages in this category, the unary sequences form a series of voiced prenasalized stops, which are not in contrast with a series of plain voiced stops. This is a common pattern, for example, in the Oceanic languages. The surface components may sometimes obscure the underlying representation, however. In some languages, such as the Indonesian language Nuaulu, underlying sequences of /nr/ surface as [nd], where /d/ does not exist (Bolton 1989). These cases of [nd] therefore do not necessarily constitute a unary sequence. The inseparability of the parts is also subject to some phonetic variation. It is not uncommon, for example, to read descriptions of prenasalized stops, such as the following one of Hoava, a language of the Solomons (Davis 2003) where the "voiced plosives are prenasalized word medially… In isolation, there is little or no prenasalization word initially… [but] there tends to be initial prenasalization when a word is inside a phrase" (23-24). Given the different aerodynamic pressures utterance-initially, as well as the lack of a preceding vowel to bear anticipatory nasalization as one cue to a following nasal consonant, it is likely the case that in many languages, an utterance-initial nasal is present but not perceptible. In the data collected for this study, for example, utterance-initial nasals are sometimes voiceless and difficult to perceive, although instrumental analysis reveals the presence of nasal airflow. In any case, such phonetic variability utterance-initially is not evidence that the sequence is phonologically separable and is not evidence against unary segmenthood.

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[1] The only language cited, to my knowledge, as having prenasalized stops and no plain nasals is the Papuan language Waris (Clements, to appear). However, this characterization appears to be based upon an error in the UCLA Phonological Segment Inventory Database (UPSID) (Maddieson 1991), as examination of the original sources (e.g. Brown 1988) reveals that the language does have a series of plain nasals.

It is quite uncontroversial to consider the sequences in this class unary segments. However, it is fair to ask whether or not these sequences form complex unary segments or whether they are simply plain voiced stops with phonetic prenasalization, as Herbert suggests. Even if the nasalization in such sequences initially arose as a strategy to reinforce voicing in stops (since leakage of air through the nose decreases supraglottal pressure and thereby facilitates the maintenance of vocal fold vibration, see e.g. Stevens, Keyser, and Kawasaki 1986), in many languages, the nasal component in such segments is a critical and non-optional aspect, participating in processes such as vowel nasalization. This suggests the need for the nasal component to be captured in the phonological representation. In addressing the second part of the primary question of this thesis—*Are the different phonological NC patterns reflected in the phonetics?*—these sequences play a critical role: they form the clear and uncontroversial class of unary NC segments.

Step two: tautosyllabic or heterosyllabic?

Having classified the inseparable NC sequences, the next step is to determine whether the remaining separable sequences are tautosyllabic or heterosyllabic.[2] Note that the interest here is in tautosyllabic onsets, both initial and medial, not codas (which have different sonority profiles and behaviors). Heterosyllabic NC sequences are quite uncontroversially considered clusters. If there is evidence for a nasal residing in coda position

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[2] Arguments for the existence of the syllable as a phonological unit have a long and rich history in phonological theory (see Blevins 1995 for an overview). The existence of the syllable will be assumed in this thesis, and alternative approaches to word structure will not be pursued here.

and an adjacent obstruent residing in a following onset, then there is no motivation for considering the sequence a unary phoneme.

Determination of syllabification is easiest in languages with a variety of consonant sequences with which to compare the NC sequences. As seen in the case of English discussed earlier, for example, the NC sequences generally behave like other clusters, occurring medially or finally where they do not violate sonority, but not initially where they would, suggesting a cluster analysis. This is a pattern seen in many other languages as well, including Indonesian. Such evidence can also work in the other direction. In some languages with many consonant sequence-types, the NC sequences pattern like tautosyllabic onsets in contrast to clear bisyllabic clusters, suggesting a tautosyllabic analysis. This is the case, for example, for the voiced NC sequences in Wolof and Sinhala and other languages to be discussed in chapter 2, section 2.1.

In the absence of other sequence-types for comparison, syllabification of an NC is often based upon its possible positions in a word. In languages where the sequences only occur medially, then it is usually assumed that the language does not allow complex onsets (otherwise they should occur word-initially as well) and therefore a heterosyllabic account is posited, further supported if the language allows final codas. On the other hand, when the sequences occur initially, a tautosyllabic analysis is often assumed (unless the initial nasal is found to be syllabic, in which case there is strong evidence for a heterosyllabic analysis).[3] If a language has tautosyllabic initial NC sequences and no other consonant sequences or final codas, this suggests the medial NCs should be treated as tautosyllabic as well, allowing the language to be characterized as having only open syllables. This is the case in many languages of Central and Southeast Sulawesi, Indonesia, for example, to be discussed throughout the thesis. (Although it is nevertheless possible to give the medial sequences a separate analysis as heterosyllabic, often evidence for doing so is lacking and the more economical tautosyllabic account that treats all sequences the same is adopted.)

Vowel alternations are sometimes used to provide evidence for NC syllabification. In Javanese, for example, Adisasmito-Smith (2004) argues that NC sequences are tautosyllabic in part because a vowel preceding a medial NC sequence does not centralize, while vowels in clear closed syllables do centralize. Evidence from vowel alternations has long been used in the analyses of NC sequences in Bantu languages. In many of these languages, vowel length is phonemic, but only long vowels occur before NCs, a process generally considered compensatory lengthening, as a vowel arguably fills a timing slot left behind by a resyllabified nasal. Evidence from vowel alternations must be viewed cautiously, however. The compensatory lengthening analysis of Bantu has been disputed, as has its evidence for NC syllabification (e.g. Downing 2005). In addition, even in languages without phonemic length contrasts, lengthening may nevertheless occur before NC

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[3] Another possibility is that an initial nasal in an NC is extra-syllabic, attached as an appendix to a higher level of prosodic structure. However, such analyses are controversial and are generally only warranted when the segmental behavior clearly falls outside the realm of the language's more general patterning (Vaux, to appear). Given the many languages in the world that have initial and medial NCs in the absence of other sequences, it is much more economical to claim the initial sequence forms a tautosyllabic sequence; the appendix analysis will not be pursued here.

sequences, as it does in Johore Malay (Teoh 1988), where there is no other evidence for a tautosyllabic treatment of the NCs. The issue of vowel length will be addressed in more detail in chapter 3, section 3.1.4.

Other methods of determining the syllable structure of NC sequences are sometimes employed, including speaker intuitions and language games. These might be useful as secondary arguments, but in and of themselves are unreliable. The first, although it may sometimes yield useful data, is often found to be problematic. In the present study, for example, speaker intuition was found to be an unreliable tool in determining syllable structure, as speakers contradicted one another and were themselves inconsistent. Language games are also sometimes used to provide evidence for NC syllabification. For example, Gil (2002) argues that a language game in Minangkabau Malay, whereby speakers transpose the first and last syllables of a word, reveals differences in syllable structure between dialects: for example, /mi**nt**a/ 'ask' becomes [**nt**ak.mi] in the Padang dialect but [**t**ak.mi**n**] in the Jambi dialect, suggesting respective tautosyllabic and heterosyllabic configurations for the NCs. Such data may support an analysis based upon the language's regular phonology, but alone should be viewed cautiously.

Step three: other evidence for a unary analysis?

Having classified the heterosyllabic clusters, the final step is to consider whether the remaining tautosyllabic sequences form unary segments or clusters. This important step in the analysis of NC status is often overlooked, however, since once the NC sequences have been determined to be tautosyllabic, a unary structure is usually automatically assumed. This assumption, without further justification, can be found time and again in descriptive sketches of languages and discussions of NC sequences: the vast majority of tautosyllabic NC analyses assume unary segmenthood. However, a unary analysis does not *necessarily* follow from a tautosyllabic structure. These are separate issues and should be treated as such when making a determination about NC structure.

The primary argument for the unary status of tautosyllabic NC sequences is sonority. Observations that syllables tend to rise and fall in sonority, with the middle of the syllable as a peak, have been noted since the 19th century, in work by Sievers (1881), Jespersen (1904), and others, and research in this area has continued to evolve (see e.g. Clements 1990, Zec 1995, Davis 1998, Gouskova 2001 and 2002). The Sonority Sequencing Principle is broadly characterized by Clements (1990, p. 285) as follows:

> Sonority Sequencing Principle:
> Between any member of a syllable and the syllable peak, only sounds of higher sonority rank are permitted

There have been different proposals as to what the exact sequencing relationship is, whether it can vary across languages, and at what level it holds. For the purposes of the present discussion, however, it is sufficient to say that by any measure, nasals are considered more sonorous than obstruents cross-linguistically. The relevance for the determination of NC sequence status, then, is that an onset sequence of NC will violate sonority, and that in order to avoid this problem, the sequence can be said to form a unary segment. Since sonority is generally understood to apply to sequences of segments, rather than segment-internally, no sonority violation is incurred.

Violations of sonority, however, certainly do occur. One of the best known cases involves the initial /s/ + stop sequences found in English and a number of other languages. These apparent violations are so common that various alternative explanations of their structure or sonority profile have been proposed (see e.g. Selkirk 1982, and discussion and references in Morelli 2003). Clements (1990) lists examples of other sonority reversals (including ***yr**a* ‘to bless’ in Ewe, ***lp**əks* ‘skin’ in Ladakhi (288)) and claims that they occur with all of the major segment classes.

Evidence from sonority can be useful in making a determination about some aspects of NC status, as seen earlier, for example, in determining the syllabification of the sequences in English, since the same observations hold of NCs and other consonant clusters. However, given that sonority violations are not uncommon and that alternative accounts are available, it should not be used as the *sole* type of evidence in making a unary determination of tautosyllabic NC sequences. This is particularly true in languages where there are no other consonant sequences with which to compare the NCs and determine how or where sonority applies. In such cases, claiming that the NC sequences constitute a complex and arguably more marked segment-type in order not to violate sonority seems no more justified than claiming that they must violate sonority in order not to force a more complex and marked segment-type. Therefore, in the absence of other types of evidence in a language, combined with no information as to how and where sonority applies, I do not consider a possible violation of sonority alone a motivation for unary segmenthood.

Turning now to the left branch of the tautosyllabic node in figure 1.3, the “other types of evidence” that might be used to determine unary segmenthood are necessarily language-specific. In short, if NC sequences appear to be treated as single segments by the phonology, in contrast to clear consonant clusters, there may be a case for unary segmenthood. In Bell's (2003) analysis of the Niger-Congo language Wolof (described by Ka 1994 and Ndiaye 1995), he argues for a unary analysis of the tautosyllabic voiced NCs, in contrast to a cluster analysis of other consonant sequences, including NC̥. In support of the NC̬ sequences being unary and the NC̥ being clusters, he offers the following evidence: NC̬ can occur after a long vowel in a monosyllable, where NC̥ (or complex codas) cannot; NC̬ can occur in an onset where NC̥ (or complex onsets) cannot; NC̬ can be part of another cluster (such as [tus.ᵑgəl] 'khôl', data from Ka 1994) whereas NC̥ cannot; and NC̬ patterns with singletons whereas NC̥ patterns like geminates (in terms of processes such as schwa insertion). Therefore, it is not clear why a medial NC sequence, for example, would have one syllabification if the obstruent is voiceless but another if the obstruent is voiced, unless the voiced sequence forms a single unit segment while the NC̥ sequence forms a cluster. The unary sequences that fall into this separable, tautosyllabic category are generally the most difficult to support and the most open to interpretation, and I suspect that many of the reported "prenasalized stops" in this category are actually clusters.

Many languages with tautosyllabic NCs lack even the types of evidence seen above, and these languages fall under the right branch of the "tautosyllabic" node in figure 1.3—"no other evidence for unary". These are usually languages that have tautosyllabic NCs to the exclusion of all other types of consonant sequences. Ironically, the NCs in these languages are even more likely to be interpreted as unary, even though there is even less evidence for such a characterization. This is the case, for example, in many languages of Central and Southeast Sulawesi, Indonesia. In a number of these languages, including Napu (Hanna and Hanna 1991), Da’a (Barr and Barr 1988), and Moronene (Anderson 1999), as well as Pamona (to be discussed in chapter 2, section 2.2.3), NÇ̬ and NÇ̥ sequences occur initially and medially alongside a series of plain voiced and voiceless consonants, and there are no final codas and no other consonant sequences. A tautosyllabic account of these languages is fairly uncontroversial, given their occurrence initially and the presence of morphological processes that illuminate this syllabification (to be discussed). However, there is no evidence that these onset sequences form unary segments. Although linguists working on these languages sometimes acknowledge the difficulty of characterizing the sequences and the arbitrary nature of their analyses, they overwhelmingly adopt a unary analysis, citing, as does Anderson in his discussion of the NC sequences in Moronene, the following three reasons: “1. There are no unambiguous consonant sequences... 2. There are no words ending in a consonant... 3. The prenasalized stops may occur word-initially...” (11). As already discussed, however, these three reasons relate only to syllable structure, not unary segmenthood.

Interestingly, linguists working on Sulawesi languages that have NC patterns similar to those mentioned above, but differing in also having geminates and final consonants, also express difficulty in the analysis of the NCs, but usually opt for a cluster characterization. This is the case, for example, in analyses of Mamasa (Matti 1991), Barang Barang (Laidig and Maingak 1999) and Pitu Ulunna Salu (Campbell 1991). (See Quick 2003 for a particularly detailed analysis of the NCs in Pendau.) Busenitz and Busenitz

(1991) allude to the arbitrariness of the different approaches to NC analysis when they tentatively propose a cluster account for Balantak but then state that “other Sulawesi languages like Uma (Martens 1988) and Ledo (Evans: n.d.) posit *similar constructions* as prenasalized phonemes” (p. 37, emphasis mine).

I make the claim that NC sequences that fall into this category—having separable tautosyllabic sequences with no independent evidence for a unary analysis—form *clusters* rather than unary NC segments. A speaker of one of these languages has no motivation for positing a unary phoneme for such a sequence. Rather, the speaker has ample evidence that nasals and obstruents independently form single segments, and no evidence that a sequence of the two warrants a special analysis, since without other sequence-types for comparison, the sonority violation offers no information about syllabification. The view taken here therefore assumes that the sequences described in many languages as “prenasalized stops” are in fact clusters. (I will return to this issue when I can bring to bear phonetic evidence.) Another possibility for the languages in this category, that a lack of clear evidence might result in speakers having different phonological representations from one another, will be briefly explored in chapter 6, section 6.1.1 and ultimately rejected.

The tautosyllabic node in the tree in figure 1.3 contains the least clear and most controversial NC cases. Interestingly, this is the category where most of the past phonological and phonetic work on NC sequences has focused, making the conflicting conclusions in past studies less surprising. I argue that the default status for sequences in this category is “cluster”, in the absence of compelling evidence to the contrary.

Summary of the approach

I have proposed a three-step approach to determining the phonological status of an NC sequence. There are two paths to unary segmenthood, and two paths to clusterhood. The inseparable unary segments on the leftmost branch, and the separable heterosyllabic clusters on the rightmost branch, constitute the clear and indisputable cases. The tautosyllabic branch in the middle contains the more controversial group. Many analyses assume that all languages that fall into this middle category must be unary segments. However, I emphasize the importance of separating the issues of tautosyllabicity and unary segmenthood. Under this approach, only those sequences with compelling evidence for unary segmenthood beyond tautosyllabicity are considered unary, whereas those languages without such evidence are, by default, clusters.

The clear unary and cluster groups on the outer edges of the tree are the ideal ones to focus on in a study that investigates the relationship between the phonology and phonetics of the sequences. Interestingly, however, past studies have usually been done with languages that fall under the less clear tautosyllabic branch. This likely explains, for example, why "unary" NC sequences in some languages have been found to have the duration of two segments: the sequences actually form clusters. The phonetic studies in this thesis investigate NC sequences on the "inseparable unary" branch (Tamambo, Erromangan) and the "heterosyllabic cluster" branch (Manado Malay), as well as a language in the "tautosyllabic cluster" branch (Pamona).

Interestingly, there is no evidence that the different sources of unary NCs or cluster NCs result in structural differences. Ultimately, it is a sequence's primary categorization—unary or cluster—that matters to both the phonology and phonetics, not the path to getting there. Therefore, the two unary types and two cluster types are not distinguished in the discussion of NC-type combinations in chapter 2, section 2.1. The phonetic data in chapter 5 will reveal that this intuition is correct.

1.4 The role of voicing in NC sequences

Many languages have both NC̬ and NC̥ sequences. However, it has long been observed that there appears to be a cross-linguistic preference for voiced NC sequences. Herbert, for example, compiles data from a number of past studies illustrating the wide variety of processes languages employ to avoid sequences of nasals and voiceless obstruents, such as through post-nasal voicing and nasal deletion. Both the presumed preference for voiced NC sequences, as well as the argued articulatory pressures motivating this distribution, have recently been a topic of discussion in the literature.

In the articulation of an NC sequence, the velum is lowered and the vocal folds are vibrating during the nasal, and then a transition occurs. In the case of a voiced NC sequence, the velum simply raises at some point before the release of the C; in an NC̥ sequence, however, the velum raises rather abruptly and the vocal folds simultaneously stop vibrating, in order to initiate the voiceless oral phase. NC̬ sequences are therefore easier to articulate, as they allow for more gradual raising of the velum (Huffman 1993). The following oft-cited quote from Ohala and Ohala (1991) illustrates why the additional effort (to produce a clear oral closure) is necessary for the perception of NC̥ sequences but not NC̬ sequences.

> [A]mong the auditory cues for a voiced stop there must be a spectral and amplitude discontinuity with respect to neighboring sonorants, low amplitude voicing during its closure, and termination in a burst; these requirements are still met even with velic leakage during the first part of the stop.... However, voiceless stops have less tolerance for such leakage because any nasal sound—voiced or voiceless—would undercut either their stop or their voiceless character. (213)

Hayes (1999), in a discussion of voicing in obstruents, argues that the post-nasal environment is the ideal environment for obstruents to voice, and also that the post-nasal environment is the most difficult for a voiceless obstruent to maintain voicelessness. Hayes and Stivers (2000) investigate these predictions with a simulation of vocal tract aerodynamics and a phonetic production study of English. They conclude that the tendency to voice obstruents after nasals is the result of two factors: the "nasal leak" observed between the articulation of a nasal and oral segment (whereby the escape of air from the nose before a complete seal is formed encourages continued voicing), and "velar pumping" (whereby a closed velum continues to raise during the articulation of the obstruent, facilitating voicing due to the expanded supralaryngeal cavity). The predicted result of these two factors is that if a language has only one NC series, it will be voiced, and only if it has nasals followed by contrasting voiced and voiceless obstruents will speakers have to invoke mechanisms to maintain obstruent voicelessness in the latter series.[4]

The role of voicing in NCs has recently generated a great deal of discussion in the literature, specifically as it relates to a topic commonly called *nasal substitution*. Nasal substitution, observed widely in Austronesian

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[4] Note that another possible NC sequence type exists—one where both the nasal and obstruent are voiceless. These interesting but unusual cases will not be pursued here. See Huffman and Hinnebusch (1998) for data on Pokoma as well as Maddieson and Ladefoged (1993) for discussion of Bondei and Bura (and references to other examples).

languages (but also found cross-linguistically), refers to a process whereby certain bimorphemic sequences of a nasal and voiceless obstruent (NC̥ sequence) are replaced by a plain nasal in order to avoid the arguably disprefered sequence of a voiced nasal followed by a voiceless obstruent (see e.g. Newman 1984). (Nasal substitution also occurs with voiced obstruents, albeit to a lesser degree.) In Indonesian, for example, the nasal in the active prefix /məŋ-/ assimilates in place of articulation to a following stop. The resulting NC sequence surfaces when the initial root consonant is voiced (a). When the initial root consonant is voiceless, however, the obstruent deletes, leaving only a nasal with the place features of the deleted obstruent (b) (e.g. Lapoliwa 1981).

(1.3)

(a)	/b/	/məŋ-**b**awa/	[məmbawa]	'to carry'
	/d/	/məŋ-**d**oa/	[məndoa]	'to pray'
	/g/	/məŋ-**g**igit/	[məŋgigit]	'to bite'
(b)	/p/	/məŋ-**p**ukul/	[məmukul]	'to punch'
	/t/	/məŋ-**t**urun/	[mənurun]	'to descend'
	/k/	/məŋ-**k**irim/	[məŋirim]	'to send'

Patterns similar to that seen above are observed in a variety of contexts across languages, where processes work to prevent NC̥ sequences while favoring voiced NC sequences.

Pater (1996, 1999, 2001) seeks to account for the nasal substitution patterns in Indonesian and other languages within an Optimality Theoretic (OT) framework (Prince and Smolensky 1993, McCarthy and Prince 1993), by proposing a highly ranked *NC̥ constraint. This constraint simply prohibits a sequence of a nasal followed by a voiceless obstruent. The result is that input NC̥ sequences surface in a variety of different ways (as described above), depending upon the ranking of other constraints in the language.

Although there appears to be widespread acknowledgment of the cross-linguistic dispreference for NC̥ sequences, questions about the nature of this dispreference, both in strength and character, have generated a great deal of controversy. Some studies propose modified or alternative OT approaches to accommodate additional data or observations (Archangeli, Moll, and Ohno 1998, Kaufman 2005, Lee 2006). Hyman (2001) argues that the opposite pattern—a dispreference for voiced NC sequences—is also attested, and that such facts support a *ND constraint (where the “D” represents a voiced obstruent). Blust (2004), in a detailed presentation of the NC facts in a number of Austronesian languages, dismantles the original *NC̥ constraint by providing many examples of exceptions to Pater’s generalizations.

In addition to arguments that the phonological generalizations may be incorrect or oversimplified, some studies have suggested that the phonetic motivations for a voiced NC preference are also questionable. Hyman (2001) claims that phonologically voiced NC sequences in some languages of the Sotho Tswana group and in the Northwest Bantu area actually undergo devoicing of the obstruent. In phonetic studies of one of these languages—Setswana—Zsiga, Gouskova, and Tlale (2006) find the devoicing to be variable (and argue against Hyman’s *ND account). Phonetic postnasal devoicing has also been claimed for the Indonesian languages Murik and Buginese (Blust 2004), although there are currently no phonetic studies to confirm this.

The issue of voicing is a crucial one in the discussion of NC sequence patterns and relates to the present study in several ways. First, in presenting the NC-type combination patterns proposed in chapter 2, section 2.1, whether or not the obstruent in a sequence is voiced or voiceless is highly important; in fact, the two types pattern quite differently. Some of the insights from the *NC̥ debate are helpful in understanding the observed patterns, while others are challenged. Second, the languages of Sulawesi, of particular interest to this study, given their interesting NC patterns and the inclusion of one of them—Pamona—in the phonetic study, offer many counterexamples to the *NC̥ claims. The unusual nasal substitution (or, more appropriately, *nasal accretion*) pattern cited by Blust (2004) for Mori Bawah, whereby a nasal prefix surfaces *only* before a voiceless obstruent (the converse of the pattern in Indonesian), is actually quite common in Central and Southeast Sulawesi languages, and is also observed in Pamona, Padoe (Karhunen 1991), Kulisusu (Mead 2001), and many other languages of the area. This topic is discussed in more detail in appendix A. Finally, the phonetic data from Erromangan collected for this study raise questions for the argued phonetic preference for voiced NC sequences. At the bilabial and velar places of articulation, phonological NC̥ sequences in Erromangan do not contrast with voiced sequences. While phonetic explanations such as those by Hayes and Stivers (2000) would predict a fully voiced articulation for these sequences, in fact the oral portion is invariably articulated as voiceless. All of these issues suggest the need to look systematically at both NC̬ and NC̥ sequences to fully understand their phonological and phonetic properties.

1.5 Representations of NC

Given that some languages have NC sequences that behave as clusters while others have sequences that behave as unary segments, and that these differences affect various aspects of the phonologies of the languages (and, as I will argue later, the phonetics as well), the differences need to be represented as structural differences in the phonology. As mentioned above, prenasalized segments have been a topic of interest for many years precisely because of the questions they raise about phonological structure. Following is a brief overview of the past proposals of their structural differences, as well as a preview of how the phonological and phonetic data investigated in this thesis bear on the representational issues.

In the *Sound Pattern of English* (SPE) (Chomsky and Halle 1968), segments are represented as unordered feature matrices. Simple segments are straightforwardly captured within this framework, where the values for a feature remain constant for a segment's duration (i.e. a plain nasal has the feature [+nasal] throughout its articulation). Segments of a more complex nature, however, those where one or more features change in value over the course of their articulation—such as affricates and prenasalized stops—are not easily captured within this framework. In SPE, the changing nature of affricates is represented with the feature [+delayed release], argued by some to extend to the case of prenasalized stops as well.

Anderson (1976), however, argues that no single value of any feature can adequately characterize prenasalized stops or other segments that are composed of both nasal and oral portions (including post-nasal and medio-nasal stops). Intrinsic to the character of these segments is that one or more features change in value over the course of their duration, similar to contour tones. Furthermore, this change may be evidenced on surrounding segments; for example, vowels commonly nasalize before a prenasalized stop (indicating that a [+nasal] feature must be available on the left edge) but not following (indicating that a [-nasal] feature must be available on the right edge). Therefore, Anderson proposes that prenasalized stops must be [+nasal] on the left but [-nasal] on the right, and captures this by assigning such segments two ordered values.

Observations such as the above by Anderson—that the linear ordering of features and one-to-one association between segments and feature matrices are inadequate to explain prenasalized stops and other segments composed of multiple phonetic parts—led to new conceptions of phonological structure. Autosegmental phonology (Williams 1971, Leben 1973, Goldsmith 1976) recognized the need for one-to-many and many-to-one mappings between segments and features, and feature geometry (Clements 1985, Sagey 1986) incorporated the need for hierarchical ordering of sub-segmental structure. (See Clements and Hume 1995 for a more detailed overview of the development of these theories.) Both insights led to new proposals for the representation of prenasalized stops.

In considering the various structural approaches to prenasalized stops, it is important to draw a distinction between contour and complex segments, as they entail different representations. Prenasalized stops are considered *contour segments*, in that the phonetic events are linearly ordered. *Complex segments* refer to those where the two phonetic entities are simultaneous, as in doubly articulated stops such as labio-velars. Affricates have traditionally been viewed as contour segments like prenasalized stops, although they have also been analyzed as complex (Hualde 1988, Lombardi 1990, Clements 1999).

Throughout this thesis, although I may sometimes use the word “complex” in a general sense in referring to prenasalized stops, I never intend that prenasalized stops are complex segments in the specific sense of labio-velars, for example, but rather are always contour.

Various feature geometric models have been posited for prenasalized stops. The proposals can be divided roughly into two categories—those that posit a single root node linked to a single timing unit (Sagey 1986, van de Weijer 1996), and those that posit two root nodes linked to a single timing unit (Clements 1987, Piggot 1988, Rosenthall 1988, Trigo 1993). (The fact that these models entail an independent timing tier, since argued by many to be superfluous, will be addressed shortly.) The difference between these two proposals can be roughly sketched as in figure 1.4:

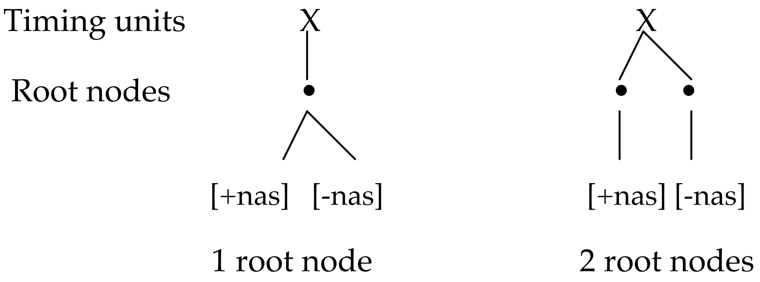

Figure 1.4: One and two-root node representations of prenasalized stops

Sagey’s (1986) argument for a single-root node analysis is a result of her proposed prohibition on branching class nodes. Van de Weijer (1996) also adopts a single-root node model, primarily because it is consistent with representations argued for elsewhere in the grammar, and because he finds the evidence for the more complex two-node structures uncompelling.

Arguments in favor of two root nodes include the single-node model's inability to represent the full range of described unary NC types (Clements 1987) and the argued need for two nodes to capture processes such as compensatory lengthening (Rosenthall 1988) and nasal harmony (Piggot 1988). A two-root node analysis is also consistent with the privative analysis of the feature [nasal] argued for by Trigo (1993). Although the above analyses differ in their specific claims about subsegmental structure and in their treatment of various technical issues related to root nodes, these points are not critical to the present discussion and will not be pursued here.

Steriade (1993) proposes a structure of prenasalized stops that differs in character from previous conceptions. In her model, plosives have two phonological *aperture positions*: a closure, characterized by a total absence of airflow (A_0), and a release (A_{max}), characterized by an approximate release. (The other option, a fricated release—A_f—is found in fricatives and affricates). The feature [nasal] can link to one, both, or none of these positions, resulting in the following segment-types:

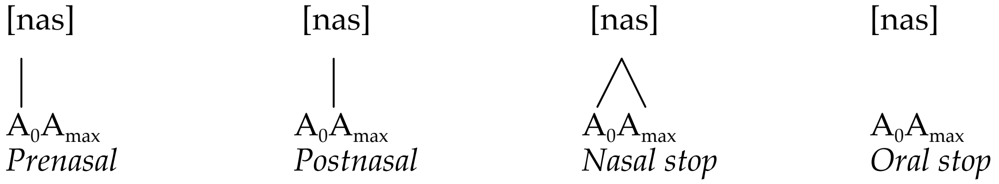

Figure 1.5: Representations of stops by Steriade (1993, p. 403)

Prenasalized stops (represented on the far left), like other stops and nasals, have two positions, with [nasal] linked to the closure but not to the release. Crucially, only segments with two aperture positions can bear a nasal contour. Since continuants in this model have only one aperture position—a release—segments such as approximates and fricatives are unable to be prenasalized.

Predictions of representations

The different representations of prenasalized stops make different predictions about the possible inventories of phonological entities and about their patterns of phonetic timing. In terms of inventories, the two-root node models can account for the full range of described NC segments (those where the two parts have different manners or places of articulation, or different voicing specifications), since two entirely separate bundles of features are involved, whereas the single-root node models, which make use of only one set of features, cannot. This distinction is important to the present discussion, as I will argue for a restricted inventory of unary segment-types, in particular for the absence of prenasalized voiceless stops, an issue taken up in chapter 2, section 2.1.

The single-node model is unable to account for prenasalized voiceless stops, where the two parts disagree in voicing, as only one voicing specification is argued to be available on the laryngeal node. Clements (1987) and Trigo (1993) see this as an advantage of the two-node model since prenasalized voiceless stops have been claimed to exist, whereas van de Weijer (1996) sees this as a disadvantage, since the overwhelming majority of described unary NC segments are voiced. (He states that prenasalized voiceless stops would require an aberrant two-root node representation, in contrast to the voiced sequences, and that this added complexity would appropriately capture the rarity of the prenasalized voiceless segments.) Steriade's (1993) model, which allows for a nasal contour only on those segments that have two aperture positions—stops and affricates—excludes prenasalized fricatives which have only one aperture position. Although her model is presumably intended to capture both prenasalized voiced and voiceless stops, I will argue in chapter 6, section 6.5.1.1, based upon the phonetic data presented in chapter 5, that it is unable to capture prenasalized voiceless stops (given that NC sequences necessarily have three positions—nasal closure, oral closure, and oral release).

The predictions about phonetic timing that arise from the representations are somewhat less obvious. The aforementioned root node models entail a separate level of phonological representation—a timing tier—intended to capture facts about timing, the implication being that the timing is not associated directly with the root nodes themselves. In both the one and two-node models, the root/s link to a single timing unit, as a way of capturing the assumption that prenasalized stops will have the duration of a single segment. (Presumably an NC cluster will have two timing units.) In a grammar that makes use of a timing tier, the two models therefore do not differ in terms of timing predictions. A separate timing tier, however, has since been argued by many to be superfluous. Moraic structure is now widely assumed rather than a timing tier, in accordance with increasing evidence for this prosodic level in the literature. (For a review of the extensive literature on this topic, see discussion and references cited by Broselow 1995). With the incorporation of a moraic level of representation, it is difficult to asses the differences between the one and two-root node models, given that these models entail other assumptions. Nevertheless, it is important to consider how the differences between the one and two-root node models would be captured in a moraic framework, and what the predictions would be for phonetic timing.

In moraic models, moras bear the prosodic weight of the syllable (with languages differing in which segments are associated with a mora, for example, in whether or not coda consonants are associated with a mora). Root nodes, which coordinate subsegmental information, capture the segmental aspects of timing, as discussed by Cohn (2003, and references therein). A separate timing tier is superfluous under such as model (and the relationship between root nodes and moras is not necessarily one to one). The number of root nodes associated with a segment therefore potentially has an effect on duration. Given that onsets are generally not weight-bearing (i.e. not associated with a mora), the roots node/s for a prenasalized stop in onset position will attach directly to the syllable. As schematized in figure 1.5 below, in a two-root node model, a prenasalized stop will be indistinguishable from an onset cluster, whereas in a single-node model, it will not. The two-root model therefore predicts that prenasalized stops and NC onset clusters will have the same duration, while single-node models predict that prenasalized stops will be shorter than onset clusters.

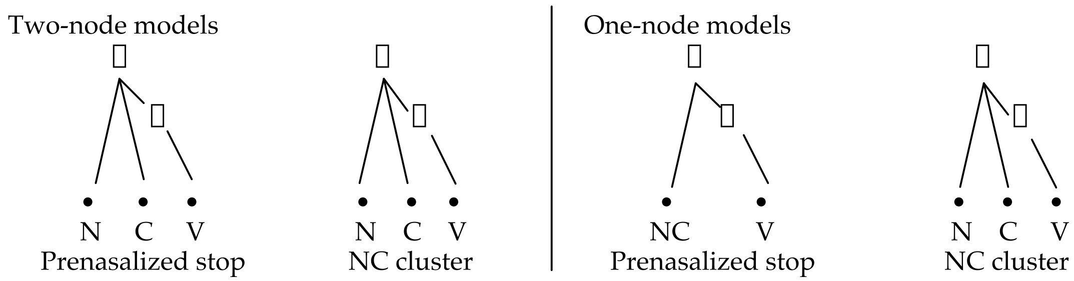

Figure 1.6: One and two-root node representations of NC sequences assuming moraic theory

The similarity between unary segments and onset clusters in the two-node model seen above is essentially that assumed by Maddieson and Ladefoged (1993) in their analyses of Luganda—a language with derived "prenasalized stops" where a moraic nasal in coda position delinks and attaches to the following onset, and Fijian—a language with underlying unary NC segments. (This case is discussed further in chapter 3, section 3.1.2.) Both the one and two-root node models predict that a prenasalized stop in an onset will be shorter than a cluster where the nasal is moraic. Where a cluster nasal is non-moraic, the single-node model still predicts a shorter unary segment, while the two-node model does not. (See chapter 6, section 6.5 for a fuller discussion of these issues.) In Steriade's model of aperture nodes, on the other hand, it appears that all NC sequences—whether unary or cluster—would be assigned the same representation. If this interpretation is correct, then this model predicts no timing difference between prenasalized stops and NC clusters.

In chapter 6, section 6.3, I return to the issue of NC representations in light of the phonological and phonetic data presented in this thesis. I argue for a single-root node account of prenasalized stops and a two-root node account of both tautosyllabic and heterosyllabic clusters. I illustrate how such representations capture the phonological asymmetries between the different NC types (including my argument for the lack of prenasalized voiceless stops developed in chapter 2, section 2.1) as well as their timing differences (in particular the shorter duration of unary NC segments as compared to tautosyllabic and heterosyllabic clusters, as seen in chapter 5).

1.6 Chapter summary

At the beginning of this chapter, I presented the primary research question under investigation in this thesis: *Are there distinct NC patters in the phonology, and if so, are these patterns reflected in the phonetics?* I argued that the answer to the first part of this question is *yes*, through an illustration of clear unary NC segments in Fijian and clear NC clusters in English. I then proposed a methodology for determining the phonological status of an NC sequence. This approach differs from others in that I do not assume that a tautosyllabic sequence is necessarily unary, in the absence of corroborating evidence elsewhere in the phonology. I then considered the role of voicing in NC sequences, followed by an overview of representational issues. All of the above topics will be developed in more detail throughout the remainder of the thesis.

1.7 Structure of the thesis

The structure of this dissertation is as follows. In chapter 2, I present a classification of NC-type combinations, as well as phonological sketches of the four Austronesian languages investigated in detail here—Tamambo and Erromangan (Vanuatu), and Pamona and Manado Malay (Indonesia). In chapter 3, I discuss phonetic NC characteristics of interest to this study, by reviewing past phonetic studies of the topic, as well as presenting the methodology used to conduct the acoustic and aerodynamic studies in this thesis. In chapter 4, I present the aerodynamic results, and in chapter 5 the acoustic results. Chapter 6 contains the discussion and conclusions.

CHAPTER TWO:
PHONOLOGICAL NASAL-OBSTRUENT PATTERNS

In chapter 1, I argued that there are phonologically distinct unary and cluster NC sequences. I also addressed the important role of voicing in characterizing NC sequence-types. In this chapter, I extend both of these discussions by presenting a classification of NC patterns in section 2.1, based upon both the unary-cluster and voiced-voiceless oppositions. Then in section 2.2, I present the phonological analyses of the NC sequences in the four languages studied in detail for this project—Tamambo, Manado Malay, Pamona, and Erromangan—and categorize their patterns in relation to the proposed classification of type combinations. Section 2.3 contains a summary.

2.1 NC type combination patterns

Given the various NC-types and the fact that languages differ in which and how many types are included in their inventories, one might imagine a wide array of type combinations cross-linguistically; however, the number of occurring patterns is actually quite limited. Not only do some NC type combinations appear to be much more common cross-linguistically than others, but certain patterns are completely unattested. In this section, I categorize and describe the attested NC type combinations, as displayed in table 2.1. I also identify certain gaps where a pattern is logically possible, yet has not been documented to occur in the phonology of any language.

In categorizing the type-combinations, I divide the NC sequences along two basic principle divisions—cluster vs. unary, and voiced vs. voiceless obstruent—resulting in four logically different classes of sequences: clusters with a voiced obstruent (NC̬), clusters with a voiceless obstruent (NC̥), unary sequences with a voiced oral portion (^{N}C̬), and unary sequences with a voiceless oral portion (^{N}C̥). Note that a division based upon place of articulation is not necessary (i.e. there is not a category with phonologically voiced NC̬ bilabials and alveolars in contrast to NC̥ palatals and velars). This is because the same generalizations about the NC sequences of a particular voicing specification (and phonological status) hold consistently across places of articulation.[1] This results in 15 possible combinations of NC-types (which I refer to as "type combinations" or "patterns"), as well as an additional type that contains no NC sequences, resulting in 16 rows in the table.

As can be seen in the table, of the 16 logically possible patterns, only six are occurring. Of the ten that are non-occurring, seven have, to my knowledge, never been attested. (These rows are shaded with solid gray.) Three other patterns have been claimed to exist but I will argue should be reanalyzed. (These rows are shaded with gray diagonal lines.) These observations can be attributed to two core results of this survey: unary and cluster NCs of the same voicing specification do not contrast within a language, and prenasalized voiceless stops do not exist. The occurring and non-occurring type combinations fall out precisely along the lines of these two observations. All ten non-occurring type combinations violate one of these principles, while none of the six occurring types do. These observations are indicated in the final column of the table, "N.O." (for "non-occurring").

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[1] The only case I am aware of where NC̬ sequences have been posited at some places of articulation and NC̥ at others is the Indonesian language Yamdena, where Mettler and Mettler (1990) list /^{m}p/ and /^{n}d/. The authors point out, however, that Drabbe (1932) claims both sequences are voiced, based upon data from a different dialect. The issue would benefit from instrumental analysis.

Table 2.1: NC type combination patterns
(white= occurring; gray= unattested; diagonal= claimed but disputed)
(N.O.= “Non-Occurring”; ^{N}C̥= due to prenasalized voiceless stop;
↔ = due to contrasting NC – ^{N}C)

		Cluster		**Unary**		
Group	**Type**	**NC̬**	**NC̥**	**^{N}C̬**	**^{N}C̥**	**N.O.**
A No NC						
B Cluster only	1a	√				
	1b		√			
	2	√	√			
C Unary only	1a			√		
	1b				√	^{N}C̥
	2			√	√	^{N}C̥
D Cluster and unary	2a	√		√		↔
	2b		√		√	^{N}C̥ ↔
	2c	√			√	^{N}C̥
	2d		√	√		
	3a	√	√	√		↔
	3b	√		√	√	^{N}C̥ ↔
	3c		√	√	√	^{N}C̥ ↔
	3d	√	√		√	^{N}C̥ ↔
	4	√	√	√	√	^{N}C̥ ↔

The evidence for these classifications is based upon my research into NC sequences in particular, and Austronesian languages more generally. This categorization is not a typology in the strictest sense; that is, it is not the result of a scientifically balanced cross-linguistic sample of segmental and phonotactic inventories. I nevertheless predict these generalizations to hold cross-linguistically and expect that the occurring and non-occurring categories posited here will extend to novel data.

In the following discussion, I present each of the occurring and non-occurring type combinations in the table. Group A includes languages that have no NC sequences; group B includes languages with only NC clusters; group C includes languages with only unary NC sequences; and group D includes languages with both unary and cluster NCs. Existing type combinations are supported with evidence from various languages cited in the literature. Non-existing type combinations are identified as such based upon a lack of attested cases or a reanalysis of claims in the literature: I take these gaps to be systematic and not accidental.

Group A: No NC sequences

Many of the world's languages fall into group A, those that do not contain any NC sequences. This fact is not surprising for two reasons. First of all, with regard to NC clusters, the cross-linguistically preferred syllable type is CV, and therefore clusters of any kind are generally disfavored. Many languages allow only open syllables, meaning that heterosyllabic NC clusters, where the nasal is in coda position, are not possible, and many also disallow complex onsets, meaning that tautosyllabic NC clusters, where more than one consonant is in onset position, are also not possible. These points are reviewed in the typologies by Blevins (1995). The result of these generalizations is that many languages do not allow any type of cluster, including NC.

Second, the relative rarity of unary NC segments cross-linguistically means that most languages do not contain prenasalized stops. Although languages with prenasalized stops are found throughout the world, their overall numbers are fairly low. According to data in the UCLA Phonological Segment Inventory Database, UPSID (Maddieson 1991), which strives to contain a genetically balanced sample of 451 languages, only five percent of the world's languages have prenasalized stops.

Given the relatively high number of languages that allow only CV syllables, combined with the relatively low number of languages that contain prenasalized stops, there are many languages in the world that lack NC sequences of any kind and therefore fall into group A. Examples from the Austronesian family include the Polynesian languages Hawaiian (Andrews 1854) and Tongan (Churchwald 1953), and the Papua New Guinea language Sinaugoro (Tauberschmidt 1999).

Group B: NC clusters only

Group B includes type combinations that contain NC clusters, but do not contain prenasalized stops. Perhaps the largest percentage of the world's languages fall into this general category. Nasals are among the most common codas cross-linguistically, and if a language is going to have heterosyllabic clusters, it will almost certainly have NC clusters among them. A combination of factors is likely the cause of the popularity of NC clusters. They are arguably easier to articulate than other cluster-types (only a change in velum position is required to produce a homorganic NC̬ sequence, and only a change in velum position and cessation of vocal cord vibration is required to produce an NC̥ sequence). In addition, the two parts of the sequence are perceptually very distinct from one another, with acoustic properties of nasality in the first portion of the sequence and acoustic properties of orality in the second, affects that are clearly manifested on adjacent vowels.

Three possible type combinations fall within group B, and each is described below. Based upon the discussion of voicing in NC sequences in chapter 1, section 1.4, we might expect that the most common type combination would be 1a, languages with only NC̬, while 1b, languages with only NC̥, would be uncommon or even non-occurring. In fact, all three of the type combinations are well-attested. As will be seen, this suggests that factors other than *NC̥ are at work.

Type combination B:1a- NC̬ only (no NC̥)

It is clear from the discussion in chapter 1, section 1.4 that many languages prefer NC̬ clusters to NC̥ clusters. It is therefore perhaps surprising that there appear to be relatively few languages that allow *only* voiced NC sequences (especially when compared to those that allow both types). The ongoing debate about *NC̥ has evolved to focus largely on a dispreference for NC̥ in derived environments, since many languages do allow NC̥ sequences root-internally. There are, nevertheless, examples of languages that allow only voiced NCs in their inventories. Mandar, a language of South Sulawesi, Indonesia described by Mills (1975) and referenced in Pater's (1999) *NC̥ discussion, has NC̬ clusters but not NC̥; rather the language currently has voiceless geminates in place of what were historically NC̥ sequences. Other

Sulawesi languages also have only voiced NC clusters, including Tolaki (Mead and Tambunan 1993).[2] Interestingly, in the cases of Tolaki and Mandar, and other languages that exhibit a voiced NC series to the exclusion of NC̥, the system is almost always a result of a *loss* of NC̥, as opposed to a situation where the language never had NC̥.

A number of phonetic studies on languages with both NC̬ and NC̥ clusters, such as English, have found that nasals are substantially shorter before voiceless stops than voiced stops, to the point where the nasal may delete entirely before the voiceless stop (Malecot 1960, see also references in Fujimura and Erickson 1997, Hajek 1997). Such weakening and subsequent deletion can result in languages of this type combination.

Type combination B:1b- NC̥ only (no NC̬)

Given the argument that NC̬ is universally preferred, it is perhaps surprising that not only are languages with only NC̥ clusters well-attested, but also that these languages appear to be fairly common, probably even more abundant than those with only NC̬. Greenberg's (1978) implicational statement that the presence of an initial NC̥ implies an NC̬ therefore does not hold true. Languages of this type combination tend to fall into four categories.

In the first category are languages with no voicing distinction, where all of the obstruents are voiceless and all of the sonorants are voiced. This is a common scenario, given that voiceless stops are often considered to be the most basic series, and the presence of a voiced series generally implies the presence of a voiceless series. In these languages, NC clusters can only occur

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[2] Although Mead and Tambunan (1993) interpret the sequences in Tolaki as unary segments, I analyze them as clusters, similar to the sequences in related Sulawesi languages, as seen in section 2.2.3.

with the voiceless stops. Examples from the Austronesian family include the Oceanic languages Ponapean of Micronesia (Harrison 1995) and Mele-Fila of Vanuatu (Clark 1991). It is important to note, however, that there has been little phonetic study of such cases, and we might therefore expect that for at least some of these languages, the obstruent portion is actually phonetically voiced. Certainly there are plenty of languages where phonological sequences of NC̥ always undergo voicing assimilation, resulting in surface sequences of only voiced NC. Underlyingly, these languages would be of type combination B:1b, and on the surface B:1a. Such cases will not be discussed further as there are clearer examples of both.

Second, there are languages with a voicing distinction that traditionally had both NC̬ and NC̥ clusters but have lost the voiced ones over time, leaving only NC̥. Court (1970) describes a process in some Indonesian languages (also discussed in Hyman's 2001 *ND proposal), whereby the voiced stop in an NC sequence preceding an oral vowel weakens to a post-ploded stop and then deletes altogether, leaving a nasal followed by an oral vowel (and distinctive vowel nasalization following nasals). He cites Sundanese, Ulu Muat Malay, Sea Dayak, and Mentu Land Dayak as examples (although Cohn 1993a finds clear oral releases following these nasals in Sundanese, which, depending upon the analysis, may be an oral stop or simply a transition). Similar observations are noted in Acehnese (Durie 1985) and Gayo (Eades 2005). (Some of these cases are likely much more complicated, however, and will be discussed in more detail in chapter 6, section 6.2.1.1). Other languages have only NC̥ as a result of the loss of the voiced NC clusters, but where the loss did not necessarily follow the above trajectory and is not evidenced synchronically by distinctive vowel nasalization, such as the Sulawesi language Uma (Martens 1988). (This case will be discussed under group C.)

Third, there are arguably languages where prenasalized voiced stops, in a language with NC̥ clusters, denasalized, leaving only NC̥ sequences alongside plain voiced (and voiceless) stops. One example is Tondano, a Minahasan language of North Sulawesi, Indonesia. Historically, all of the voiced stops in Tondano were prenasalized (Watuseke 1985); in addition, Tondano allowed a variety of consonant clusters, including NC̥ clusters, making it a group D language (one with both prenasalized stops and NC̥ clusters). More recently, however, the prenasalization is being lost in some dialects, leaving plain voiced stops that are never preceded by nasals, alongside NC̥ clusters (Sneddon 1975).

Fourth, there are cases where a parent language had only voiced NC sequences but where some of the daughter languages devoiced the obstruent. This appears to be the case in several languages of the Markham family (Adzera, Wampur, and Wampar). Holzknect (1989) reconstructs Proto-Markham as having voiced NC sequences, while three of the twelve daughter languages have corresponding NC̥ sequences in their synchronic grammars. (These cases will be discussed further under group C.)

In addition to the languages that offer clear examples of this type combination, it is interesting to note that there are languages that, although they may have both NC̬ and NC̥ sequences, exhibit a preference for NC̥. This is the case in many languages of Central and Southeast Sulawesi, for example, where processes such as nasal accretion (mentioned briefly in chapter 1, section 1.4) are more likely to produce NC̥ sequences than NC̬ sequences. Such phenomena are discussed in more detail in appendix A.

Type combination B:2- NC̬ and NC̥

As stated at the outset of the group B discussion, many of the world's languages have NC clusters. While some have only NC̬ clusters, and others have only NC̥ clusters, the majority of them have both. Perhaps if a language has NC clusters in its inventory, the contrast will be exploited by having them wherever possible, including before both voiced and voiceless obstruents. (Indeed, as previously discussed, many languages that today have only one type of NC cluster did formerly have both.) Some languages have NC clusters alongside a wide variety of other cluster-types, including various languages of the Philippines, such as Tagalog (Schachter and Otanes 1972) and Ilokano (Rubino 1997). Other languages allow NC sequences to the exclusion of all or most other cluster-types, including many of the Sulawesi languages to be described throughout this chapter and several Oceanic languages that allow NC clusters on a very limited scale, such as Iaai (Lynch 2002) and Gapapaiwa (McGuckin 2002).

Group C: Prenasalized stops only

Many languages have prenasalized stops to the exclusion of NC clusters, as well as to the exclusion of most other cluster-types. In fact, an interesting observation about languages with prenasalized stops is that they seem to disproportionately have only open syllables. Given the discussion of the NC classification tree in chapter 1, section 1.3, one can speculate as to why this might be the case. Inseparability of NC components is the strongest piece of evidence for unary segmenthood. If a language has codas, it will likely have nasal codas; if there are nasal codas word-medially, there will be contexts where a nasal and a following stop are adjacent, meaning clear NC clusters.

Once there are clear NC clusters in the language, it might be the case that all NC sequences are more likely to be interpreted as clusters.

In the previous discussion of the group B languages, I argued that languages with only NC̥ sequences are well-attested, perhaps even more so than NC̬ sequences. While we might expect this generalization to apply to prenasalized stops as well, the facts here are different. As can be seen in table 2.1 above, I argue that only one type combination in this group actually occurs, that is C:1a—languages with only ^{N}C̬—while two others have been claimed to exist but are not well supported by the phonological evidence. This relates to a more general issue—lack of ^{N}C̥.

Type combination C:1a- ^{N}C̬ only (no ^{N}C̥)

Of those languages that do contain prenasalized stops in their inventories, the vast majority of them are of this type combination (among both the group C and group D patterns), having prenasalized voiced stops to the exclusion of other NC sequences of any kind. These languages generally (although not always) have a prenasalized voiced series of stops alongside a plain voiceless series, with no plain voiced stops. In a sense, the prenasalized series *is* the voiced series. The oft-cited example of Fijian, already discussed in chapter 1, section 1.1, is one member of this category. Other Austronesian examples include Ambea of Vanuatu (Hyslop 2001), Longgu of the Solomon Islands (Hill 2002), and Tinrin (Osumi 1995) of New Caledonia.

Excurses: Prenasalized voiceless stops

In order to address the possible existence of the other two type combinations in this group, it is necessary to examine a more fundamental question: Is there any convincing evidence for the existence of prenasalized voiceless stops? Prenasalized voiceless stops have been claimed to exist in a small number of languages. As is the case with prenasalized stops in general, however, in many cases the classification is merely descriptive, and there is not necessarily phonological evidence for a unary analysis. Furthermore, where there is only a single NC series, there is no evidence in most cases that the obstruent portion is truly voiceless. Both of these points will be discussed further as I present the type combinations. A review of many of the proposed cases of prenasalized voiceless stops reveals that, at best, all candidates for such a segment-type are debatable, and that there are no undisputed cases of prenasalized voiceless stops (as compared to the many clear cases of prenasalized voiced stops). I argue that in fact prenasalized voiceless stops do not exist. It is of course difficult to argue for the absence of a segment, but a review of the putative cases so far suggests that this claim is correct.

Reports of languages with prenasalized voiceless stops are quite rare. Ferguson's (1963) survey of nasal universals, which categorizes "prenasalized (voiced) stops" among the secondary nasal consonant types, does not even mention prenasalized voiceless stops. In the UPSID database (Maddieson 1991), only seven of 451 languages are listed as having prenasalized voiceless stops (about 1.5 percent). As a review of the original sources on which the inventories are based suggests, however, even for this small amount of cases, the languages are either better characterized as having clusters or as having voiced prenasalized stops. These cases will be reviewed shortly. The rarity of this potential segment-type is of course not evidence that it does not exist. In fact, one could argue that the presumed dispreference for NC̥ sequences in general (as discussed in chapter 1, section 1.4), combined with the relatively small number of languages that contain prenasalized segments of any kind, results in their rarity. However, the fact that there are few candidates overall is a consideration, especially given that the validity of these candidates is called into question.

In languages with both NC̬ and NC̥ sequences, where a claim is made that one or both series form unary segments, one of two scenarios generally occurs. First, in some languages, the NC̬ sequences are seen to pattern differently from the NC̥—with the former exhibiting the behavior of unary segments and the latter of clusters. This is the case, for example, in Wolof and Sinhala, to be discussed later. Languages such as these would therefore fall under group D (having both unary and cluster NCs). It is never the case, to my knowledge, that the NC̥ sequences are the ones to exhibit unary behavior while the NC̬ sequences exhibit cluster behavior. Why should this be the case if prenasalized voiceless stops exist?[3] Second, in the languages where both ^{N}C̬ and ^{N}C̥ are said to occur, there is not clear phonological evidence for the phonological status of the sequences. These cases will be discussed under type combination C:2 below.

The most striking observation about all languages where prenasalized voiceless stops have been reported, whether or not they are said to exist alongside a voiced series, is that there is always a series of plain voiceless stops (and plain nasals). There are no reported cases, to my knowledge, of a language with a series of ^{N}C̥ segments in the absence of voiceless stops. These sequences are therefore always separable, and the best piece of evidence for

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[3] One might argue that there is an implicational relationship, whereby a language must have prenasalized voiced stops in order to have prenasalized voiceless (opposite of the scenario with geminates, for example, where voiced geminates imply voiceless). This argument is questionable, however, since NC̥ clusters do not imply NC̬ clusters (where the geminate scenario reflects consonant patterning more generally: voiced stops imply voiceless stops).

unary segmenthood—inseparability of nasal and oral elements—is not available. This stands in contrast to the majority of prenasalized voiced cases, and notably the clearest cases, where the prenasalized voiced series occurs in the absence of a plain voiced series. This important but overlooked characteristic of NC̥ sequences—that NC̥ sequences always occur alongside plain voiceless obstruents—is the key phonological reason to cast doubt on the existence of prenasalized voiceless stops. I further develop the arguments against prenasalized voiceless stops in the following discussions of the two non-occurring type combinations.

Type combination C:1b- ^{N}C̥ only (no ^{N}C̬)

Languages claimed to have a series of prenasalized voiceless stops as their sole NC series are often those that have no voiced stops. There is reason to look upon such claims with suspicion. Oftentimes, when a language has no plain voiced stops, a linguist proposing a phonemic inventory will choose not to include voicing as a distinctive feature, stating that the contrast between the plain voiceless stops and prenasalized stops is one of prenasalization only, regardless of the whether or not there is actually voicing during the oral portion of the NC. This is the case, for example, in Yuanga, a language of New Caledonia, where Schooling (1992) lists a series of prenasalized voiceless stops, but acknowledges that the motivation is theoretical and that the sounds are actually voiced. These languages would be better classified as belonging to type combination C:1a, those with only prenasalized voiced stops.

Of the seven languages listed in UPSID as having prenasalized voiceless stops, three are claimed to have only a prenasalized voiceless series (not a voiced series), and these are also languages where all of the plain stops are also voiceless—Tiwi, Gelao, and Yanyuwa. Based upon a review of the sources cited in UPSID, however, I suggest that the evidence in these cases is not convincing; not only can the voicing status of the obstruents be questioned, but also the unary status of the sequences.[4] First, the voicing of the oral portion is not clear in any of these cases. In Tiwi (Osborne 1974), the plain stops are said to voice variably, in free variation, and /t/ in particular always voices after a nasal; these factors raise the possibility that the NCs are better characterized as voiced. In Gelao (He 1983), there is no discussion of the voicing character of the oral portion, and listing the sequences as prenasalized voiceless may be an attempt to maintain symmetry in the system, especially given that it is a language of China, and sources often do not discuss voicing as a distinctive feature. (In addition, the occasional use of a voiced aspiration diacritic after the NCs may be an effort to indicate obstruent voicing.) In Yanyuwa (Huttar and Kirton 1981, Kirton 1967, Kirton and Charlie 1978), the plain stops are described as being variable in voicing, with no comment on voicing in the post-nasal environment (and all stops are represented with voiced symbols). A comment by Kirton and Charlie that word initially, the *nasal* in an initial NC is often devoiced might be the reason for the prenasalized voiceless classification in UPSID. Second, the unary status of the sequences can be questioned in all cases. No sources offer clear evidence for unary segmenthood in these languages, and most sometimes use the term "cluster". In addition, all of these languages have properties that call into doubt the unary characterization. Gelao and Yanyuwa both have other clear consonant clusters as well as codas (albeit limited for Gelao in both

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[4] One to three sources are cited for each of these languages in UPSID; I consulted all where possible, and these are referred to in the above discussion.

cases). In Tiwi, the NCs only occur medially (and are transcribed as heterosyllabic), and in cases where initial NCs surface due to deletion of an intervening vowel, the nasals are syllabic.

In addition to cases where putative prenasalized voiceless stops are said to occur in the absence of plain voiced stops, there are also cases where these NCs are reported alongside both plain voiced and voiceless stops. One of these is Uma, a Central Sulawesi language described by Martens (1988) (who confirms that the oral portions of the sequences are indeed phonetically voiceless, p.c., June 1, 2006). In Uma, the only consonant sequences allowed are NC̥ sequences which occur initially and medially (both monomorphemic and bimorphemic), and there are no final codas. Martens analyzes these sequences as unary. However, like many of the Central Sulawesi languages (most of which have both NC̬ and NC̥ sequences), there is no evidence for unary segmenthood. There is simply an assumption that they must be unary segments because they can occur initially (presumably based on sonority, even though there are no other consonant sequences for comparison with which to learn about the sonority profile of the language), and therefore I classify them as tautosyllabic clusters. Similar cases are observed in the Markham family of Papua, referenced above, and described by Holzknect (1989). Several of these languages have NC̥ sequences but no NC̬ sequences, in contrast to the majority of languages in the family that have both NC̬ and NC̥, or only NC̬. At least in Adzera (Amari dialect), for which a phonological sketch is available (Holzknect 1986), the sequences can occur initially and medially, as can C + /r/ sequences, and there are final codas. As with Uma, there is no evidence that the NC sequences necessarily form unary segments, simply the observation that they are one of the few types of consonant sequences allowed, and that they do occur initially.[5] The key point about the languages claimed to be potential examples of this type combination is that their NC patterns are consistent with those described as B:1b above—languages with NC̥ clusters. Therefore, lacking evidence to the contrary, I classify these languages as cluster languages, according to the methodology presented in chapter 1, section 1.3.1.

Type combination C:2- ^{N}C̬ and ^{N}C̥

Even without the preceding arguments that prenasalized voiceless stops do not exist, the cases claimed for this type combination—languages with both ^{N}C̬ and ^{N}C̥ —are very weakly supported. All of the languages reported to be of this pattern also have plain voiced and voiceless stops as well as plain nasals, meaning that the NC sequences fall into the "separable" category. Although described as prenasalized, the NC sequences in languages reportedly of this pattern often either have plausible alternative analyses or simply lack the phonological evidence to characterize them with certainty, thus not warranting their inclusion in an otherwise unsubstantiated group. In short, although there may be reported cases of such languages in the literature, there are no uncontroversial cases as there are in the other well-attested type combinations, and the data can be reasonably accounted for in other ways.

In this group of languages, the NC̬ and NC̥ sequences pattern in the same way as one another, but they do not pattern differently from other consonant clusters in the language in a way that would indicate a unary

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[5] Howard (2002), whose thesis focuses on discourse referents in Adzera, agrees with Holzknect's analysis of prenasalized stops. However, in the dialect he studies (central dialect chain, as spoken in Sangang), he does not observe the NC sequences occurring initially or following another consonant. I view this as corroborating evidence that, at least for this dialect, the sequences are likely clusters.

analysis for the NCs in contrast to clear clusters. Part of the problem is that most of the cases claimed to be of this type combination (some of which are discussed below) are languages where NC sequences occur to the exclusion of all, or most, other sequences. Since the NC sequences generally occur word-initially and there are no final codas, a tautosyllabic analysis is posited and a unary account is therefore assumed. As argued in chapter 1, section 1.3, however, evidence beyond tautosyllabicity is needed before a unary determination can be made. The fact that the NC sequences in these languages generally occur in the absence of other sequences is alone an interesting observation. If both prenasalized voiced and prenasalized voiceless stops can occur, then why should they not occur in a language together, alongside non-NC consonant clusters? After all, there are clear cases of languages that have prenasalized voiced stops and also clusters of other consonant types.

Many Bantu languages have traditionally been described as having prenasalized voiced and voiceless stops, and these languages represent perhaps the largest number of possible candidates for this type combination. The unary NC analysis, however, has more recently been challenged in various Bantu languages (Herbert 1975 for Luganda, Hubbard 1995a for Luganda and Runyambo, Kula 1999 for Bemba, Walker 2000 for Yaka). Downing (2005) provides a detailed analysis of why Bantu NC sequences are best analyzed as clusters, including evidence that such sequences are clearly input clusters, that the nasal is moraic both word-initially and medially, and that pre-NC lengthening (often cited as evidence that an NC sequence is syllabified in onset position, triggering the lengthening of a preceding vowel) can be accounted for even with the nasal residing in coda position. This brief discussion of Bantu by no means provides a complete argument against the existence of prenasalized stops in any of the individual languages. However, the general descriptive characterization of Bantu as having prenasalized voiced and voiceless stops, a characterization that does not necessarily hold up to detailed analysis, is a good example of how the descriptive accounts of "prenasalized stops" in some languages may not provide evidence for phonological unary segments.

Also appearing on the surface to offer good evidence for the existence of this type combination are the languages of Central and Southeast Sulawesi, Indonesia, including many of the Kaili-Pamona languages, such as Da'a and Napu; Bungku-Tolaki languages, such as Moronene and Wawonii; and Muna-Buton languages, such as Muna and Wolio.[6] In most of these languages, the only consonant sequences allowed are NC sequences; they occur both initially and medially, and there are no final codas.[7] Unlike in the Bantu languages, where there are vowel alternations or other processes that shed more light upon the structure of the NC sequences, there is often no such information in the Sulawesi languages. In the sketch of the Sulawesi language Pamona in the section 2.2.3, I develop a case for why the NC sequences are better characterized as tautosyllabic clusters than prenasalized stops. In short, although there is strong evidence that the sequences are tautosyllabic, there is no corroborating evidence for a unary characterization, leading to a cluster analysis. I make this case specifically for Pamona, but predict that is also the correct analysis of the other related Central and Southeast languages with similar NC patterns.

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[6] See e.g. for Da'a (Barr and Barr 1988), Napu (Hanna and Hanna 1991), Moronene (Anderson 1999), Wawonii (Mead 1998), Muna (van den Berg 1989), Wolio (Anceneaux 1952).

[7] Historically, these languages did have final codas that were lost (Sneddon 1993).

Three of the seven languages listed in UPSID as having prenasalized voiceless stops are of type combination C:2—Sama, Hadza, and Konyagi. The first, Sama, is a language of South Sulawesi (Verheijen 1986). The author states that the occurrence of NCs after long vowels provides support for a unary analysis; however, while this may suggest that the sequences are tautosyllabic, it provides no evidence of unary segmenthood. Further, the sequences are very limited initially, and the language has geminates (indicating the presence of codas). In the Hadza source (Tucker, Bryan and Woodburn 1977), there is no evidence presented for the unary status of the NCs, and it is not clear whether the NC̥s can occur word-initially. For the third language, Konyagi, I was unable to attain the source (Santos 1977). The final language of the seven listed in UPSID is apparently of a third type. Hmong, Miaoyu dialect (Wang 1985, Purnell 1972) is noted with two series of prenasalized voiceless stops, one being aspirated and one unaspirated. Although assumed to be unary in the original descriptions, evidence for such an analysis is not presented (and the language does have other sequences and nasal codas, albeit limited). The voicing quality of the sequences is also unclear. Other sources describe the unaspirated series as voiced (Lyman 1979 and Smalley 1976, as cited by Maddieson and Ladefoged 1993), and the tone pattern appears to group the unaspirated NC series with voiced sounds (Wang 1985). Further, the presence of phonemic voiceless nasals raises the possibility that the nasals in the aspirated series are phonologically voiceless. This interesting case would benefit from more detailed study.

Another observation about potential candidates for this type combination deserves mention. There are no attested cases to my knowledge of languages that have prenasalized voiced and prenasalized voiceless stops to the exclusion of plain voiced and voiceless stops. If languages of this type combination do exist, it is not clear why this should be the case. As pointed out above, there are no attested cases of prenasalized voiceless stops in the absence of plain voiceless stops; however, there are many cases of prenasalized voiced stops in the absence of plain voiced stops, so why is there always a series of plain voiced stops as well as a series of plain voiceless stops in these cases? These facts cast additional doubt upon the existence of this type combination.

Group D: NC clusters *and* prenasalized stops

Nine of the 16 logical NC patterns fall into group D, those containing at least one unary segment and one cluster. Interestingly, of these nine, only one type combination is occurring—2d, languages with prenasalized voiced stops and NC̥ clusters. One other type combination has been claimed to exist (3a), but I argue (following previous researchers) that it should be reanalyzed. Strikingly, seven other cases have never even been claimed to exist. Given the argument that prenasalized voiceless stops do not occur, we might at least expect the elimination of the six type combinations that contain them. I will argue that there is an additional motivation for ruling out many of these cases, as well as for ruling out the other type combination that we might predict should occur (2a). I first discuss the occurring type combination, then the disputed one, and then I discuss the remaining unattested cases as a whole.

Type combination D:2d- NC̥ and ^{N}C̬

A number of languages reportedly fall into this group, having prenasalized voiced stops but NC̥ clusters. These languages can be further divided into two categories, those with “inseparable” prenasalized stops (where there is not also a plain voiced series), and those with “separable” prenasalized stops (where there is also a plain voiced series). The first category contains the clearest cases, as the NC sequences are indisputably unary. One such language is Erromangan, an Austronesian language of the Oceanic family in Southern Vanuatu. In Erromangan, all obstruents are voiceless, with the exception of a prenasalized /^{n}d/. The language allows a large number of cluster-types, among them NC̥, and the result is a voiced unary segment /^{n}d/ in contrast with an NC̥ cluster /nt/. Erromangan is one of the languages examined in detail for this study, and more information about its phonology can be found in section 2.2.4. Also in this category are certain dialects of Tondano. As discussed in subcategory B:1b, while some dialects have denasalized the prenasalized stops, others have retained them, along with the NC̥ clusters, making these dialects examples of this type combination (Merrifield and Salea 1996).

In languages of the second variety, where NC̬ and NC̥ sequences exist alongside plain voiced stops, the two sequence-types are observed to have different phonological behaviors, with the NC̥ sequences patterning like other clear clusters and the NC̬ sequences patterning like single segments. In chapter 1, section 1.3, I reviewed such an argument for the analysis of Wolof. The status of the NCs in languages of this type combination tend to be more controversial, likely because the existence of plain voiced stops complicates the analysis of the NC sequences. However, this type combination is already validated by the more straightforward cases in the preceding paragraph.

Type combination D:3a- NÇ̬, NÇ̥ and ^{N}Ç̬

If both NC clusters and NC unary segments exist in the world's languages as phonological entities, then we would expect that some languages would contrast a unary and cluster NC of the same voicing specification, for example /^{n}d/ and /nd/. However, very few such languages have been reported in the literature, and the handful of cases where such a contrast has been posited are somewhat controversial and have been reanalyzed. Of the languages argued to be of this type combination—those with prenasalized voiced stops, as well as both NÇ̬ and NÇ̥ clusters—it is the fact that unary and cluster NCs of the same voicing specification are said to contrast that is notable, not the fact that a contra-voiced cluster also occurs (since, as established, many languages have both NÇ̬ and NÇ̥ clusters). Therefore, in the following discussion, I focus on the purported ^{N}Ç̬ - NÇ̬ contrast, not the presence of NÇ̥. It is worthwhile to reconsider the data in these claimed cases to see if the languages do in fact offer clear evidence of this type combination. I will argue that this described contrast can only occur if independent structural properties are in place (in particular, a singleton-geminate contrast), and that a more illuminating alternative analysis is appropriate.

Perhaps the best known case of a language with a reported unary-cluster NC contrast is Sinhala. Sinhala has contrasting pairs of words such as the commonly discussed /la^{n}da/ 'thicket' and /landa/ 'blind' (as well as words with /nt/ sequences). Such a contrast has been noted, for example, by Coates and De Silva (1961), and subsequently by a number of authors. Letterman

(1997) groups the analyses of this contrast into two classes—those who analyze the contrast as one between a prenasalized stop and an NC cluster (e.g. Karunatillake 1987, Kenton 1987, Gair 1988) and those who analyze the contrast as one between a tautosyllabic cluster and a heterosyllabic cluster (Coates and De Silva 1961, Feinstein 1979). Either way, the relevant point that both groups intend to capture is that the contrast between such words appears related to the syllabification of the nasal, i.e. whether it is tautosyllabic in the onset with /d/ or resides in the preceding coda. If the latter group is correct, then Sinhala is not even a candidate for this group, as there would be no unary-cluster contrast (although the syllabification differences would raise other interesting issues). Particularly relevant for the present discussion is whether or not the first view is possible, that the contrast seen above is actually one between a unary segment and a cluster. I will argue that a third view is correct.

Although their analyses differ, both Maddieson and Ladefoged (1993) and Letterman (1997) argue that the contrast in Sinhala is not one of a unary NC segment versus a cluster, but rather of a singleton versus a geminate, citing both phonological and phonetic evidence. Sinhala has a phonological contrast between singleton and geminate consonants, and the alternations between these two types of segments appear to be parallel to the alternations between the sounds described as /ⁿd/ and /nd/. I focus first on Letterman's more detailed discussion.

Letterman argues that the contrast in Sinhala is between a prenasalized stop and a geminate prenasalized stop, by citing evidence that the prenasalized stops undergo gemination just as other singletons do. (The data cited by Letterman 1997 and reproduced below is from Disanayaka 1991 and

Karunatillake and Inmam 1991).[8] In example (2.1) below, gemination of a singleton occurs in the singular of inanimate nouns (a), the plural of animate nouns (b), and the causative of verb forms (c). The first example in each set illustrates a plain consonant undergoing the process, while the second in each set illustrates a prenasalized stop undergoing the same process.

(2.1)

(a)	/pot□/[9]	'bark'	[potu]	plural	[pottə]	singular
	/ho^{m}bu□/	'chin'	[ho^{m}bu]	plural	[hombe]	singular
(b)	/balal/	'cat'	[balala]	singular	[balallu]	plural
	/polo^{n}g/	'viper'	[polə^{n}ga]	singular	[polongu]	plural

(c)	[madinəwa] non-past generic	'brush'	[mædda] simple past	[maddənəwa] causative
	[i^{m}binəwa] non-past generic	'kiss'	[imba] simple past	[imbənəwa] causative

The above examples illustrate that prenasalized stops are affected by the same gemination processes that affect regular singletons. The parallel behavior of the prenasalized stops and the regular singletons leads Letterman to conclude that the described unary-cluster contrast in Sinhala is actually a singleton-geminate contrast. Such an analysis is consistent with the other patterns in the language, and it does not necessitate a separate process whereby a prenasalized stop becomes a cluster in the same environment as the gemination environment. Additionally, in phonetic experiments conducted by Letterman, she finds that the duration of a plain geminate nasal and the

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[8] In addition to the examples included here, Letterman also cites data in favor of analyzing the prenasalized segments as tautosyllabic, but as the tautosyllabicity of such sequences is not questioned in the various analyses; I do not review such evidence here.

[9] □ represents an empty moraic slot.

duration of a purported geminate prenasalized stop are virtually identical. These phonetic data will be reviewed in chapter 6, section 6.4.1.

Maddieson and Ladefoged (1993) also claim that the contrast in Sinhala is due to gemination, but they state the difference as one between a tautosyllabic NC cluster and an NC cluster with a geminate nasal, rather than as one between a prenasalized stop and its geminate, i.e. between /landa/ ‘thicket’ and /lannda/ ‘blind’, for example. At least with regard to the present point, the difference between these two analyses is only notational. Both Maddieson and Ladefoged (1993) and Letterman (1997) agree that there is a tautosyllabic NC sequence of some sort in an onset, and that the nasal portion of this sequence geminates, resulting in a nasal in the preceding coda. The difference is in whether or not the tautosyllabic NC sequence actually forms a unary segment. Letterman believes that it does, citing evidence such as the prohibition against most other onset clusters in the language, the fact that final prenasalized stops reduce to single velar nasals just as all other final nasals do (/tæn/ ‘places’ [tæŋ#]; /li^{n}d/ ‘wells’ [liŋ#]), as well as the violation of sonority in a tautosyllabic NC sequence. Maddieson and Ladefoged claim that the sequence is a cluster, although the question of segmental structure in such cases is not their focus. Like Letterman, Maddieson and Ladefoged include phonetic evidence illustrating that the heterosyllabic NC sequence is longer than the tautosyllabic one. In the end, the data cited in both papers are consistent with either analysis. What is relevant to the present discussion is that there do seem to be strong arguments in favor of the contrast in Sinhala between described /^{n}d/ and /nd/ being one of a singleton versus a geminate, rather than between a unary segment and a cluster.

Two other languages have been described as having a unary-cluster NC contrast. The first of these, Fula, a Niger-Congo language of West Africa described by Arnott (1970), has been reanalyzed by Maddieson and Ladefoged (1993) in a similar fashion as Sinhala, where the purported unary-cluster NC contrast is actually one of a tautosyllabic cluster versus an NC cluster with a geminate nasal. The second of these is Selayarese, an Austronesian language of South Sulawesi, Indonesia, described by Mithun and Basri (1986). In a sketch of the phonology, the authors state that the language has a contrast between unary NC sequences and clusters. The authors list a few descriptive examples but do not otherwise provide evidence for their analysis. The language also has singleton-geminate contrasts elsewhere in the phonology, although it is not known how the NC patterns might relate to these. This case needs to be investigated in more detail. Regardless of how any of the above languages are analyzed, however, it is significant to note that all three have singleton-geminate contrasts more broadly, and that at least in the cases of Sinhala and Fula, the phonological evidence shows that the “unary” NCs pattern with singletons, while the “cluster” NCs pattern with geminates. It is likely not a coincidence that the only reported cases of a unary-cluster NC contrast in the literature have this property in common. In each case, the most economical and illuminating analysis is that it is a singleton-geminate contrast that underlies the apparent unary-cluster contrast.

If it is the case that no language contrasts unary and cluster NC sequences apart from an independently motivated singleton-geminate contrast, which is the position taken here, then this observation must be explained. I will argue that this fact is directly related to the phonetic characteristics of the NC sequences, more precisely that the phonetics of NC sequences restrict the possible phonological contrasts. The fact that all reported cases of languages with the aforementioned contrast can be analyzed instead as having a singleton-geminate contrast is important to this argument. The details of this analysis are developed in chapter 6, section 6.4.1.[10]

Group D- the remaining type combinations

The remaining seven type combinations in group D are all unattested, and all of them are ruled out on the basis of preceding arguments. First, all but one of these patterns (2c) contain contrasting unary and cluster NCs of the same voicing specification. As just argued above, it appears to be the case that no language has such a contrast. Not only is it significant that only one type combination (of the possible seven with such a contrast) has even been claimed to exist and that all three languages that were candidates have a more illuminating alternative characterization, but also that *all six of the other possible types are entirely unattested*. As is evident when looking at table 2.1, out of all of the possible combinations of (zero), one, two, three, or four segment-types in the table, *at most two may occur in any given language*. This may involve two clusters, or one prenasalized stop and one cluster, but in no case a contrast between a unary and cluster NC with the same voicing specification.

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[10] Two other cases deserve mention here. First, Ciyao (Hyman and Ngunga 1997), has also been described as having a contrast between NC clusters and prenasalized stops. However, the nasal from the medial cluster is argued to be non-moraic and forced to syllabify in the following onset, resulting in a surface prenasalized stop. The unary vs. cluster contrast is therefore always neutralized, with both NC-types appearing as prenasalized stops on the surface. Ciyao is an interesting case but does not bear directly on the present discussion. Second, some dialects of Japanese, notably Tohoku, contain voiced stops that prenasalize inter-vocalically (Shibotani 1990, Nasakawa 2005). The relationship between these stops and NC clusters in the language warrants fuller study. (Thank you to John Whitman for discussion of this case.)

Second, I argued in the preceding discussion that prenasalized voiceless stops do not exist. Of the non-occurring group D cases, six of the eight contain prenasalized voiceless stops. It is a noteworthy observation, in considering the evidence for and against prenasalized voiceless stops, that in many possible type combinations where they could logically exist, they do not. Although many of these non-occurring type combinations are also ruled out on the basis of contrasting unary-cluster NCs of the same voicing specification, in the case of type combination 2c, where /nd/ would contrast with /ⁿt/, it is simply the non-existence of prenasalized voiceless stops that predicts the lack of this pattern.

2.1.1 Summary

In the preceding discussion, I have argued for a particular classification of NC sequence patterns. Of the 16 logical NC patterns (including one with no NCs), only six are occurring. Possible type combinations include languages with NC̬ clusters, NC̥ clusters, or both, languages with only prenasalized voiced stops, and languages with prenasalized voiced stops and NC̥ clusters. One of the interesting observations about these combination patterns is that languages with only NC̥ sequences are quite well-attested, contrary to expectation. The existence of all of these type combinations is well supported by cases in the literature.

The ten non-occurring cases can be attributed to two factors. First, there are arguably no languages that contrast unary and cluster NC sequences of the same voicing specification, resulting in many gaps in group D. Second, there are no clear cases of prenasalized voiceless stops, resulting in gaps in groups C and D. I will argue in chapter 6, section 6.4 that both of these gaps can be explained in part by the phonetic characteristics of NC sequences. A revised table (table 2.6), containing only the attested types, along with examples, will be provided at the end of this chapter. Now, I turn to the analyses of the four primary languages in this study.

2.2 NC analyses of the four languages under investigation

In this section, I present phonological analyses of the NC sequences in Tamambo, Manado Malay, Pamona, and Erromangan. These analyses are the result of fieldwork I carried out on each of these languages. The details of these studies, including information on speakers and on the methodology of elicitation, are presented in chapter 3, section 3.2.

For each of the languages, detailed phonological studies were undertaken, including extensive investigation of the NC sequences. In the interests of focusing the present discussion, however, I present only the most relevant points from the NC analyses, including the phonemic inventories of consonants and the classification of the NCs following the methodology outlined in chapter 1, section 1.3.1. These short sketches are excerpts from longer and more detailed studies by Riehl (2006b).

2.2.1 Tamambo

Tamambo is spoken on the western half of Malo island in the Pacific island nation of Vanuatu, and is classified as a Southern Oceanic language, of the North Vanuatu linkage (Lynch, Ross and Crowley 2002). There are approximately 2000 native speakers, with perhaps as many as 4000 total speakers if second-language speakers are included (Lynch and Crowley 2001). The most comprehensive work on Tamambo has been done by Dorothy Jauncey, who completed a grammar (1997) and a dictionary (1998). In addition, Riehl and Jauncey (2005) published an illustration of the sound system; other materials in Tamambo are referenced by Lynch and Crowley (2001). The generalizations presented here are based upon data collected in the capital of Port Vila, Vanuatu from March-July 2005.

Consonant phoneme and NC sequence inventory

The phonemic consonant inventory for Tamambo is presented in table 2.2 below. This inventory, which is based on the variety of the language spoken by the group of young adult speakers living in Vila who participated in this study, differs slightly from that described by Jauncey (1997) and Riehl and Jauncey (2005), where the authors make generalizations about the language across a broader range of speakers.[11]

Table 2.2: Phonemic consonant inventory of Tamambo

	Bilabial	Labialized bilabial	Labio-dental	Alveolar	Post-alveolar	Velar
Plosive	**^{m}b**	**^{m}b^{w}**		t **^{n}d**		k
Affricate					**^{n}dʒ**	
Nasal	m	m^{w}		n		ŋ
Trill				r		
Fricative			f	s		x
Approximate				r		w
Lateral approximant				l		

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[11] Jauncey (1997) and Riehl and Jauncey (2005) list the prenasalized palatal stop /^{n}ɟ/ in place of /^{n}dʒ/, the bilabial fricative /β/ in place of /f/, and the labialized bilabial fricative /β^{w}/ in place of /w/.

As can be seen in the table, Tamambo has a series of NC̬ sequences, involving the stops and affricates, alongside a series of plain nasals and plain voiceless stops, with no series of plain voiced consonants. The prenasalized notation on the plosives and affricates in the table presupposes a unary analysis. This is the characterization I will argue for below.

The NC sequences occur at the bilabial, labialized bilabial, alveolar, and post-alveolar places of articulation. Only at the alveolar place of articulation is there both an NC̬ sequence and a voiceless stop. The labialized bilabial /$^{m}b^{w}$/ is marginal for these speakers.

Analysis of NC sequences

As discussed in chapter 1, section 1.3, the first step in determining NC sequence status is to identify whether the sequences are separable or inseparable. In Tamambo, the sequences are inseparable; there is no series of plain voiced stops, rather they always occur with a preceding nasal component. There are also no phonological alternations that suggest the NC sequences are a result of two underlying phonemes. In addition, the plain nasals, although they occur independently, never occur adjacent to any other consonant-type, including the voiceless stops. The analysis of the NC sequences in Tamambo is therefore quite straightforward: the sequences form unary segments. This analysis is consistent with that found in the other sources on the language, and the presence of an inseparable voiced prenasalized series is a common characteristic of an Oceanic language.

As argued in chapter 1, section 1.3, inseparability is a sufficient criterion for unary segmenthood. However, there is corroborating evidence in support of this analysis in Tamambo. First, the sequences have a distribution identical to other obstruents in the language: they occur word-initially and medially, but not finally. Second, there are no other consonant sequences in the language, suggesting that no clusters—heterosyllabic or tautosyllabic—are allowed. Third, there is little evidence for codas in the language, with the exception of a few nasal suffixes (and a handful of nasal-final words resulting from vowel deletion), suggesting that no codas are allowed word-medially. I refer the reader to the aforementioned sources for additional details.

2.2.2 Manado Malay

Manado Malay, also referred to as Minahasan Malay and Manadonese, is a Western Malay-Polynesian language spoken primarily in the province of North Sulawesi, Indonesia. It is one of many varieties of Malay and is the lingua franca of this region, with an estimated two million first and second language speakers (Stoel 2005). There has been relatively little linguistic work on Manado Malay, although limited phonological descriptions can be found in Maluegha's (1977) brief grammatical sketch, Lalamentik's (1984) thesis on Manado Malay speakers' pronunciation of English, Salea-Wartou's (1985) short dictionary, Prentice's (1994) grammatical sketch, and Stoel's (2005) book on focus. Sources that cover other aspects of the language are referenced by Collins (1996) and Stoel (2005). A recent work not listed in these publications is Warokka's (2004) comparative dictionary of Manado Malay and several Minahasan languages. The Manado Malay data for this study were collected in the city of Manado from February-April 2005.

Consonant phoneme and NC sequence inventory

The consonant inventory for Manado Malay, as spoken by the group of young adults living in the provincial capital of Manado who were the subjects of this study, is in table 2.3. This inventory is in agreement with that presented by Stoel (2005) but differs in several ways from other sources.[12]

Table 2.3: Phonemic consonant inventory of Manado Malay

	Bilabial	Alveolar	Post-alveolar	Palatal	Velar	Glottal
Plosive	p b	t d			k g	ʔ
Affricate			tʃ dʒ			
Nasal	m	n		ɲ	ŋ	
Trill		r				
Fricative	f	s				h
Approximant				j	w	
Lateral approximant		l				
NC sequences	mp mb	nt nd	ntʃ ndʒ		ŋk ŋg	

As can be seen in the table, the language has a series of voiced stops, a series of voiceless stops, and a series of plain nasals. The language also has NC sequences occurring with all of the stops and affricates, both voiced and voiceless. In addition, NC sequences occur with the fricatives (/nf, ns/).

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[12] Maluegha (1977) and Lalamentik (1984) include the velar fricative /x/, but my speakers have no corresponding sound in the provided examples (i.e. they say [sok] rather than [sxok] for 'shock'). (Perhaps this borrowed sound from Dutch is now only found in the speech of the elderly.) Salea-Wartou (1985) and Prentice (1995) include /v/ in addition to /f/, although my speakers have only the latter; likewise the /z/ included by Prentice (1995) is not found in the speech of my subjects who have only voiceless /s/. Finally, instead of /w/, Maluegha (1977) includes /v/ while Lalamentik (1984) uses /ʋ/; indeed, there is great variability in the production of this phoneme.

Analysis of NC sequences

The first step in the analysis of the NC sequences is to determine whether or not the NC sequences are separable or inseparable. In the case of Manado Malay, the sequences are clearly separable. All of the obstruents and all of the nasals can occur both in sequences and independently. Further, the obstruents can combine with other consonants as well. For example, /b/ can occur alone, as in /bu**b**ur/ 'porridge', in an NC sequence, as in /a**mb**e/ 'to take', or adjacent to other consonants, as in /ke**rb**au/ 'buffalo' .

Given that the sequences are separable, the next step in the analysis is to determine whether or not they are tautosyllabic or heterosyllabic. Based upon the phonotactics of the language, it is clear that they are heterosyllabic. First, the sequences do not occur in initial position, even though other sequences do, for example /**pl**uŋku/, 'punch', /**sm**eŋkin/, 'lipstick'. All initial sequences obey sonority (with the exception of /s/, which appears to have a special status in many languages), suggesting that sequences of falling sonority such as NC cannot be tautosyllabic in an onset. Second, sequences that do not rise in sonority are limited to word-medial position where presumably they can be heterosyllabified, for example [he**k.t**ar] 'stapler', [a**l.f**o.kat] 'avocado', suggesting that the syllabification of medial NCs is similar, for example, [a**m.p**a] 'four', [ba**ŋ.k**u] 'sofa'. Third, codas are common, not only in word-medial position as in the above examples, but finally as well, for example /udʒa**ŋ**/ 'rain', /re**ts**/ 'zipper', further supporting the analysis of the medial nasals in NC sequences being in coda position. Fourth, there is some evidence from vowel alternations that a vowel followed by NC is in a closed syllable. High front vowels, in particular, optionally centralize before a final closed syllable or before NC, for example, [pinsil] ~ [pɪnsɪl] 'pencil', [linta]

~ [lɪnta] ‘leech’, but not before a plain nasal, for example [lima] ~ *[lɪma] ‘five’. These alternations give further support to the claim that a nasal in a medial NC is in a coda.

In chapter 1, section 1.3, I argued that separable, heterosyllabic NC sequences are necessarily clusters. Given that all of the Manado Malay NC sequences clearly fall into this category—NC̬ and NC̥ alike—the NC sequences in the language are analyzed as clusters.

2.2.3 Pamona

Pamona, or Bare’e, is a Western Malayo-Polynesian language of the Kaili-Pamona subgroup in Central Sulawesi, Indonesia, spoken by approximately 106,000 speakers (Barr and Barr 1979). The most comprehensive research undertaken on Pamona was by Adriani, in the late 19th and early 20th centuries, who completed a dictionary (1928) and grammar (1931), as well as other publications referenced by Noorduyn (1991). Aside from the discussion in Adriani’s grammar, there has been little treatment of Pamona phonology in the literature, with the exception of short sketches included in reports published by the government’s Center of Language Learning and Research (Pusat Pembinaan Dan Pengembangan Bahasa), including Rozali, Hente, Saro and Lumentut (1981), Najoan (1981), and Hente, Kadir and Bouti (1994), as well as two unpublished theses by students at Indonesian institutions, referenced by Noorduyn. The phonological and phonetic data for this project were collected in Indonesia from December 2003 to March 2004, with a brief follow-up in March 2005.

Consonant phoneme and NC sequence inventory

The inventory of consonant phonemes in Pamona is in table 2.4 below.

Table 2.4: Phonemic consonant inventory of Pamona

	Bilabial	Alveolar	Post-alveolar	Palatal	Velar	Glottal
Plosive	p b	t d			k g	ʔ
Affricate			dʒ			
Nasal	m	n		ɲ	ŋ	
Fricative		s				
Approximate		r		j	w	
Lateral approximant		l				

NC sequences mp mb nt nd ŋk ŋg ntʃ ndʒ

As can be seen in the table, Pamona has series of plain voiceless stops, plain voiced stops, and plain nasals. In addition, NC sequences occur with all of the obstruents, including both voiceless and voiced stops, as well as the voiced affricate and the fricative /s/ (the latter resulting in the sequence [ntʃ] , to be discussed). I will argue below that the sequences in Pamona form clusters. Although Adriani (1931) lists the sequences as prenasalized stops in his inventory, this classification seems to be more descriptive than analytic (and he implies in later discussion that he views them as clusters).

Analysis of NC sequences

The first step in analyzing the sequences is to determine whether or not they are separable or inseparable. With the exception of /ntʃ/, all of the sequences are separable. Any of the obstruents or nasals can occur either independently or in an NC sequence, for example /ku**m**u/ 'sarong', /ta**b**o/ 'bowl', /wo**mb**u/ 'door'.

The case of /ntʃ/ is somewhat different, as [tʃ] is not an independently occurring phone in the language but only appears following a nasal component. There is evidence, however, that /ntʃ/ results from a sequence of underlying /ns/. /ns/ never appears on the surface, and when /n/ and /s/ become adjacent across a morpheme boundary, the result is [ntʃ], as in:

(2.2)

moN-	+	saiwe	montʃaiwe, *monsaiwe
ACTIVE		'mop'	'to mop'

The situation is somewhat complicated by the appearance of certain unanalyzable monomorphemic words, such as /a**ntʃ**a/ 'mango' and /to**ntʃ**i/ 'bird'. However, given the frequency of phonological alternations such as that seen above, and the fact that /n/ and /s/ are in complementary distribution, I analyze [tʃ] as an allophone of /s/, and /ntʃ/ as a cluster.

Having concluded that the NC sequences are separable, the next step is to determine whether they are tautosyllabic or heterosyllabic. In Pamona, the NC sequences are the only consonant sequences in the language; therefore it is not possible to compare their patterning or behavior with that of other sequences. Nevertheless, there is evidence that they are tautosyllabic. First, the sequences can occur word-initially, as /**mb**awu/ 'pig' and /**ŋk**ai/ 'grandfather', and there is no evidence that the nasals in such forms are syllabic. Therefore, the sequences are necessarily tautosyllabic in this position. Second, the language allows no final consonants. This fact, combined with the observation that there are no indisputable cases of medial heterosyllabic sequences, suggests that all syllables are open, and further suggests that the medial sequences are tautosyllabic as well. Third, certain morphological patterns are consistent with a tautosyllabic analysis. For example, there is a reduplication process that copies both syllables of a disyllabic verb, lending the meaning “to do X repeatedly or continuously”, as in:

(2.3)

/ma-doŋi/	‘to hear’	[ma.do.ŋi.do.ŋi]	‘to hear continuously’
/ma-oli/	‘to buy	[ma.o.li.o.li]	‘to shop continuously’

When the above active prefix appears before a voiceless obstruent, an alternate with a nasal appears (this *nasal accretion* process is discussed in more detail in appendix A). An NC sequence therefore forms at the morpheme boundary, and in the reduplicated form, the nasal is copied along with the base:

(2.4)

/maŋ-koni/	‘to eat’	[ma.**ŋk**o.ni.**ŋk**o.ni]	‘to eat repeatedly’
		*[maŋ.ko.ni.ko.ni]	
/maŋ-tima/	‘to take’	[ma.**nt**i.ma.**nt**i.ma]	‘to take repeatedly’
		*[man.ti.ma.ti.ma]	

The fact that the nasal from the prefix is copied along with the base suggests that when the base reduplicates, the nasal is in the onset with the obstruent. Although this evidence is not conclusive (since alternative analyses are possible), it is consistent with the tautosyllabic analysis, and when taken into account with the other evidence, contributes to the likelihood that all NC sequences in Pamona are tautosyllabic and all syllables are open.

Now that the NC sequences have been characterized as tautosyllabic, it is necessary to determine whether or not there is any evidence for unary segmenthood. Although sonority is often invoked at this stage in an analysis, I argued in chapter 1, section 1.3 that sonority alone is not a sufficient argument for a unary account, particularly in a language like Pamona where the lack of other consonant sequences means it is not possible to determine if or where sonority applies. Other evidence is needed in order to argue that these sequences are unary, but no other evidence is available. There are no vowel alternations, no stress shifts, no phonological processes of any kind to suggest to the speakers that it is necessary to posit a complex unary phoneme for the NC sequences. Therefore, in keeping with the arguments presented earlier, I give a default analysis of “cluster” to the sequences in Pamona. I expect that this same analysis is also accurate for the other Central and Southeast Sulawesi languages that exhibit the same NC patterns, some of which have been mentioned in earlier discussions.

There is additional evidence that is consistent with a cluster analysis. Although these points alone do not provide a case for clusterhood, they are more straightforward to account for in a cluster analysis than a unary analysis. First, Pamona has NC̥ sequences and N-fricative sequences, both argued not to exist as unary segments cross-linguistically (see section 2.1 of this chapter and Steriade 1993, respectively); given that these sequences pattern just as the other sequences do, there is reason to believe that all sequences are clusters. Second, the language has both monomorphemic and bimorphemic NC sequences (which would mean that at least some of the prenasalized stops would need to be derived). Third, in some related languages with similar NC patterns, there is corroborating evidence that the sequences are clusters; for example, in Tukang Besi, NC̬ sequences alternate with geminate nasals (Donohue 1999), suggesting that, at least in such languages, the NC sequences are clusters. Fourth, Pamona’s NC̬ and NC̥ sequences behave differently with regard to morphological alternations; for example, as seen in appendix A, the addition of various morphemes to a stem results in the appearance of a nasal before voiceless stops but not voiced stops. There is no evidence to suggest that the NC̥ sequences form unary segments in contrast to the NC̬ sequences; however, their differing behaviors in these environments would be very hard to explain if all sequences were unary. Further, as will be seen in chapter 5, section 5.4, the phonetic data are consistent with a cluster account.

2.2.4 Erromangan

Erromangan, also referred to as Sye (or Sie), is spoken on the island of Erromango in Vanuatu. It is classified as a Southern Oceanic language in the Nuclear Southern Oceanic linkage (Lynch, Ross and Crowley 2002), and is spoken by approximately 1900 people on the island of Erromango in Vanuatu (Lynch and Crowley 2001). The most comprehensive research on the language has been undertaken by Crowley and includes a grammar (1998) and dictionary (2000). Capell and Lynch have also contributed to the language's description. Their works, as well as additional articles by Crowley and others, are referenced by Lynch and Crowley (2001). Throughout this section, two references in particular will be frequently cited and discussed, Crowley (1998), hereafter "Crowley" and Capell and Lynch (1983), hereafter "Capell and Lynch". The data for this project were collected from May through July 2004, in Port Vila, the capital of Vanuatu.

Consonant phoneme and NC sequence inventory

The consonant phonemes for Erromangan are in table 2.7. The consonant inventory presented here differs from that by Capell and Lynch in several small ways.[13] It differs from Crowley's in the analysis of the prenasalized stop, to be discussed below.

Table 2.5: Phonemic consonant inventory of Erromangan

	Bilabial	Labio-dental	Alveolar	Palatal	Velar	Glottal
Plosive	p		t $^{\text{n}}$**d**		k	
Nasal	m		n		ŋ	
Trill			r			
Fricative		v	s		ɣ	h
Affricate						
Approximate				j	w	
Lateral approximant			l			
NC sequences	mp		nt ($^{\text{n}}$d)		ŋk	

Erromangan has a series of plain voiceless stops, plain nasals, and a voiced alveolar NC sequence, listed above as a unary segment (a point to be discussed below). In addition, as can be seen directly below the table, NC̥ sequences occur with the voiceless stops. I argue that the voiced alveolar sequence is a unary segment, and that all other NC sequences are clusters.

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[13] Capell and Lynch include the velarized bilabials /p^{w}/ and /m^{w}/, and they include both /f/ and /v/. Crowley argues that the velarized bilabials are not phonemes, but consonant clusters, and that the voiceless labiodental fricative is simply an allophone of /v/; while I am in agreement with Crowley on these points, these issues were not systematically studied for this project.

Analysis of NC sequences

In Erromangan, the NC̬ sequences and NC̥ sequences differ in behavior. Therefore, I analyze the two groups separately, beginning with the NC̬ sequences.

NC̬ sequences

There is one NC̬ sequence in the language, at the alveolar place of articulation. The first step in the analysis of its status is to determine whether the sequence is separable or inseparable. In Erromangan, this sequence is clearly inseparable. The voiced obstruent portion, [d], only occurs with a preceding nasal component. This is in contrast to all of the other obstruents in the language, which can occur independently. Further, /^{n}d/ patterns like a single segment. It frequently occurs initially, as in /^{n}domo/ ‘strong’, and although other NC sequences are possible initially, they optionally allow insertion of a schwa, as in [nvat] ~ [nəvat] ‘stone’, an alternation never found with /^{n}d/ sequences (*[nədomo]). The sequence also occurs medially following other consonants, where normally only two adjacent consonants can occur, including in monomorphemic forms as /tit^{n}dit/ ‘dusk’ and bimorphemic forms such as /iror-^{n}dal/ ‘she and several others’. In such forms, there is no indication that the nasal is syllabic. (There is limited and conflicting evidence that /^{n}d/ can also occur word-finally, but these facts are not reviewed here.)

The inseparability of /^{n}d/ leads to a unary analysis of the sequence. This is the position taken here, and also by Lynch and Capell. Crowley, however, analyzes the sequence as an underlying /nr/ cluster, which surfaces as [^{n}d]. There are two primary reasons for this analysis, which I argue against in the following discussion.

First, Crowley claims that across morpheme boundaries, /n+r/ sequences surface as [nd]. However, there is no evidence that such an alternation is productive in the synchronic grammar. Crowley states that when the nominalizing prefix /n-/ is added to a verb root beginning with /r/, the result is [nd]. However, r-initial verbs are extremely rare, and there is only one in the dictionary with which to test this claim—/rovoh/ 'clear garden site', which is also the word used to exemplify the claim by Crowley, where /rovoh/, is [rovoh] 'clear garden site' but [ndovoh] 'clearing garden site' with the addition of the nominalizing prefix. My primary speakers were somewhat inconsistent in their pronunciation of these forms, although both did sometimes have [^{n}d] in the nominalized form.

Given the lack of additional nominalization candidates to test, I explored the concatenation claim with the only other /n/- final prefix, /ovn-/ 'many', on all of the /r/- initial nouns in Crowley's dictionary (a total of 12 words). Interestingly, in all cases where speakers would accept this concatenation, the result in normal speech was not [nd] or even [nr], but rather [ndr]. For example:

(2.5)

/ovn-/ 'many' +	/ramal/	'skink'	[ovondramal]
	/renvau/	'cottonwood'	[ovondrenvau]
	/romɣoi/	't.o. plant'	[ovondromɣoi]

In careful speech, however, speakers sometimes pronounced the forms with just the plain /r/ as in [ovonramal]. With no other candidate prefixes, as well as no appropriate words of the form /r_____n/ in the data with which to observe /n+r/ concatenation in reduplication, there are no opportunities to observe what happens when these two sounds come together. Although there may be some evidence for an underlying /n+r/ in the case of the word /rovoh/, there does not appear to be evidence from other words, either presented by Crowley or in the data collected for this study.

Crowley (p.c., July 7, 2005) mentioned that one of his primary reasons for thinking that [nd] arises from /nr/ is in comparing the forms [ndan] ‘day’ and [mran] ‘tomorrow’, which he posits as /n-ran/ and /m-ran/, respectively, the former resulting in hardening due to the presence of the /n/. However, the word [ran] does not occur independently, so there are no alternations, and it is therefore not clear that these words are morphologically complex in the synchronic grammar. Rather, it is likely that they are fossilized forms.

While it may be the case that historic /n+r/ (via a nominalizing prefix) gave rise to all of the /^{n}d/ sounds in the present language (and indeed there are a large number of /n/-initial words in the language today), there does not seem to be evidence for an underlying cluster in the synchronic grammar. There are a large number of monomorphemic /^{n}d/ words with no evidence of underlying /nr/. A few examples (from Crowley 2000) include:

(2.6)

Initial		Medial	
nde	‘blood’, *n*	*nande*	‘wild nutmeg’, *n*
ndivkau	‘type of vine’, *n*	*nenduγ*	‘garden’, *n*
ndevsin	‘in the direction of’, *loc*	*tandγon*	‘smash to pieces’, *v*

Crowley’s second argument in support of the /n+r/ analysis is that there are no surface [nr] sequences, initially or medially. While this is true, and indeed may be a gap left as a result of historic concatenation, it is also true that many other consonant cluster combinations that could exist do not. Among these is [nl]. The absence of initial and medial [nl] seems to me to be no more or less peculiar than the absence of [nr]. Therefore, this gap in the phonotactics does not offer much support for an /n+r/ analysis.

The cluster analysis for /^{n}d/ cannot be supported; this, combined with the fact that this frequently occurring sequence is inseparable, leads me to conclude that the sequence is a unary segment, in agreement with Capell and Lynch. I do not, however, take a stance as to whether all cases of /^{n}d/ historically arose from /n+r/ (as suggested by Crowley) or if it is the reflex of the Proto-Oceanic prenasalized trill (as suggested by Lynch 2001).

NC̥ sequences

All of the NC̥ sequences in Erromangan are separable. In this way, they differ from the voiced sequence discussed above. The voiceless stops can occur independently, as in /u**t**ar/ 'fight', following a nasal, as in /ta**nt**op/ 'tall', or adjacent to other consonants in medial position, as in /u**tp**on/ 'elbow'.

Given that the NC̥ sequences are separable, the next phase is to determine whether they are tautosyllabic or heterosyllabic. The answer to this question is fairly straightforward in the cases of /mp/ and /ŋk/, which I discuss first. These two sequences never appear initially (or finally), but only in medial position. This distribution suggests that they must be heterosyllabic, appearing only where the two parts can be separated into two syllables, as in [lo**m.p**ot] 'type of plant' and [no**ŋ.k**o] 'straight' (or potentially syllabified together in a coda word-medially when followed by a third consonant, [ta**mp.n**um] 'successor', although such examples are rare). Further, as seen in the preceding examples, Erromangan does allow codas, both medially and finally, making the coda analysis of a medial nasal in an NC̥ quite straightforward. Like /mp/ and /ŋk/, sequences of /nt/ are common word-medially. In this position, they are presumably heterosyllabic, parallel to /mp/ and /ŋk/ and the many non-suspect medial clusters, including heterorganic NC cases such as [na**m.k**ar] 't.o. fern'. (There is limited evidence that /nt/ can occur word-finally as well, although these data are not reviewed here.)

The facts concerning /nt/ are somewhat more complicated, however. There is some evidence that /nt/ can occur word-initially; however, this evidence is difficult to interpret. Crowley (2000) lists a very large number of words with initial <nt>, all of which are listed with the alternative pronunciation <t>. (Many forms are listed under both <n> and <t>, others just under <n> and others just under <t>, although it is not clear what, if anything, distinguishes the three sets). However, both during routine elicitation for this study, as well as through methodically checking the pronunciations of many of these words as listed in the dictionary, the speakers in this study never pronounced the nasal in the words when uttered in isolation, and only occasionally pronounced a nasal when a vowel preceded across a morpheme boundary, although when prompted, most speakers did say that the pronunciation with a nasal was acceptable. For example:

(2.7)

Isolation form			Connected speech	
[toɣ]	*[ntoɣ]	'sea'	[ra toɣ] ~ [ra ntoɣ]	'to the sea'
[tompi]	*[ntompi]	'fig'	[hai tompi] ~ [hai ntompi]	'a fig'

This observation about /nt/ sequences is in contrast to the /ⁿd/ sequences where the nasal is always noticeably produced. If not for the large number of forms listed with initial /nt/ in Crowley (2000), I would have considered the sequence to be very uncommon (although still occurring) initially. (Its rarity is perhaps why Capell and Lynch do not include /nt/ among their examples of initial consonant sequences.)

A possible explanation for the confusing behavior of initial /nt/ may relate to the large number of nasal-initial roots in the language. According to Crowley, most of the words in Erromangan, including well over half of the nouns, begin with a nasal, the result of an historic nasal article which is not synchronically divisible. It may be that speakers optionally append a nasal to roots beginning with other initial consonants, by analogy. The appearance of such a nasal would be more noticeable among the set of /t/-initial words, given that there are a larger number of /t/-initial words than there are words that begin with other obstruents. This tentative explanation finds some support with /p/-initial words. Several words with initial /p/ selected for the recording task were occasionally pronounced with a preceding nasal during the recordings. For example, E4 pronounced *pap* 't.o. fish' as [pap] seven times but as [mpap] three, and E3 pronounced *pau* 'term of affection' as [pau] eight times but as [mpau] twice.

If it were not for the complicated status of /nt/ in initial position, a heterosyllabic account of the sequence would be straightforward, given the common occurrence and consistent realization of the sequence word-medially. Initially, the fact that the nasal in /nt/ almost never surfaces (in the absence of a preceding vowel) may suggest that it deletes in this position due to a constraint against tautosyllabic /nt/. Although other views on the initial /nt/ sequences are possible, I nevertheless argue that a heterosyllabic account is the most compelling for /nt/, although this interesting case would benefit from additional research.

I have argued in this section that Erromangan has one prenasalized stop /^{n}d/ and three NC clusters /mp, nt, ŋk/. Erromangan is an interesting addition to the phonetic studies for two reasons. First, unlike the other three languages, there are both unary and cluster NCs in this language. Second, the NC̥ sequences at the bilabial and velar places of articulation are not in contrast with voiced NC sequences. We might therefore expect that the obstruent portion of these clusters will voice, at least variably, in Erromangan (based on predictions in chapter 1, section 1.4), as opposed to Pamona and Manado Malay where a contrast between NC̬ and NC̥ must be maintained. As the phonetic data in chapter 5 will reveal, however, these sequences in Erromangan are almost always articulated as voiceless.

2.3 Chapter summary

In this chapter, I have proposed a typology of NC sequence patterns. An important outcome of these discussions is that no language contrasts unary and cluster NCs of the same voicing specification, and also that prenasalized voiceless segments are non-occurring. The result is that only six of the possible sixteen NC pattern types are attested.

I also analyzed the NC sequences in the four languages whose phonetic data will be presented in chapters 4 and 5. I argued that two of these languages, Manado Malay and Pamona, fall into group B (type combination B:2), having NC̬ and NC̥ clusters. One language, Tamambo, falls into group C (type combination C:1a), having only voiced unary NCs. The final language, Erromangan, falls into group D (type combination D:2d), having clusters with voiceless stops and unary NCs that are voiced. Interestingly, however, since the prenasalized series in Erromangan contains only one segment, at the alveolar place of articulation, the language may be said to fall under group B (type combination B:1b), having only clusters with voiceless stops, at the other places of articulation, an observation which I will argue has consequences for the phonetic realization of the sequences. Although the languages in group B differ in the syllabification of the clusters—Pamona being tautosyllabic and Manado Malay heterosyllabic—I will illustrate in chapter 5 that it is the unary-cluster distinction, rather than the tautosyllabic-heterosyllabic distinction, that is relevant for the phonetic realization. Table 2.6 below contains a revised classification of NC patterns, excluding the ten non-occurring type combinations and including only the six attested patterns, along with examples of each.

Table 2.6: Revised table of NC type combination patterns, containing only occurring patterns. Primary languages under investigation are bolded and underlined.

		Clusters		**Unary**	**Examples**
Group	**Pattern**	NC̬	NC̥	ᴺC̬	
A					Hawaiian, Sinaugoro
B	1a	√			Tolaki, Mandar
	1b		√		Uma, Ponapean
	2	√	√		**Pamona, Manado Malay**
C	1a			√	**Tamambo,** Fijian
D	2d		√	√	**Erromangan,** Tondano

In chapter 3, I discuss the phonetics of NCs sequences and the methodology used to undertake the acoustic and aerodynamic studies of the four languages investigated in detail.

CHAPTER THREE:
PHONETICS OF NASAL-OBSTRUENT SEQUENCES AND METHODOLOGY

The main question under investigation in this thesis is: *Are there distinct NC patterns in the phonology, and if so, are these patterns reflected in the phonetics*? In chapters 1 and 2, I argued that the answer to the first part of this question is *yes*, that there are distinctive NC patterns (specifically unary versus cluster) in the phonology. Beginning with this chapter and continuing throughout the rest of the thesis, I address the second part of the question, and I argue that this answer is also *yes*, that the different phonological NC patterns do have different phonetic realizations. In section 3.1 of this chapter, I discuss the phonetics of NC and present four hypotheses to be tested, and in section 3.2, I discuss the methodology of the study.

3.1 The phonetics of NC sequences

In order to address the question of whether or not phonological NC patterns are reflected in the phonetics, it is necessary to determine what phonetic characteristics might be of relevance. Three issues often surface in such discussions—NC total duration, degree of nasalization in the preceding vowel, and duration of the preceding vowel. In this section, I present the claims in the literature about each of these three factors as they regard NC sequences. First, however, given the great importance of duration to the present study, I present some background information on the topic, including a general discussion of the many factors affecting duration, and some of the particular phonetic affects on segmental duration.

3.1.1 Duration- Background

Factors affecting duration

Many difficulties arise when trying to make generalizations about data based upon duration values. This is because duration is dependent upon many different factors—most of which will not be relevant to the point being investigated. Both linguistic and extralinguistic factors play a role. Linguistic factors might include, for example, the segmental neighborhood of the sound being investigated—is the duration of the token under study affected by the manner or place of articulation of a preceding or following consonant? They may also include prosodic factors, such as where the token falls in relation to word position and stress, and what sort of intonational phrase is associated with the utterance. Extralinguistic factors include speaker-specific qualities such as gender, age, body size, and characteristic rate of speech; environmental factors such as relative loudness or softness of non-speech noises in the environment; or psychological factors such as a speaker's mood, degree of comfort, and desire to articulate clearly or discretely.

Klatt (1976) provides an overview of segmental duration in English. Phonological units in his model have inherent duration, and this duration is affected by numerous factors. He divides these factors into seven broad categories—Extralinguistic, Discourse Level, Semantic, Syntactic, Word Level, Phonological/Phonetic, and Physiological, referencing studies by a number of researchers that show these factors at work. To cite just one example, he observes that "there is more than an 8:1 range of systematic variation in observed vowel durations in spoken sentences" (1210).

It is possible to control for linguistic factors to some degree. Tokens to be compared can be observed in minimal sets—controlling for segmental environments, and they can be uttered in frame sentences—controlling for prosodic factors. Although such steps are crucial, they cannot completely eliminate non-relevant variation. In some cases, for example, it may not be possible to place a particular sound in a minimal set with a sufficiently comparable form. Further, even if words are uttered in a consistent frame sentence, a speaker's intonation may change over multiple repetitions, perhaps indicating either boredom with the frame sentence, or on the other hand, increased comfort. Extralinguistic factors can be controlled for to some degree as well, though this is even more difficult. Speakers can be asked to speak at a "normal" rate, and their responses can be controlled by revealing tokens at steady intervals, rather than having them read a wordlist, for example. However, completely controlling for rate of speech is impossible. Many speakers tend to speed up as the task goes on, and others insist on careful enunciation, which is not always possible to identify, especially if the listener is not a native speaker of the language.

The best way to ensure that duration data are as accurate as possible, in addition to instituting controls such as those described above, is to record multiple repetitions of multiple speakers. In this way, one can more easily determine typical duration values while factoring out idiosyncratic aspects of some speakers' productions as well as unusually slow or fast articulations by a particular individual. In addition, given that speakers and languages do have characteristic duration patterns, it is important to make relative comparisons rather than broad generalizations; for example, claiming that the nasals in language X are much longer than language Y is not necessarily useful if in fact all sounds in language X are longer. These issues will be discussed in more detail throughout this chapter, when evaluating past studies and when presenting the methodology for the present study. Ultimately, the goal is to understand the interaction of the many factors affecting duration, but the narrower goal in the present context is to control non-relevant factors in order to assess the effect of duration on the realization of unary and cluster NCs.

Phonetic affects on segmental duration

The phonetic interest in this thesis is in whether or not phonological structure is reflected in some way in the phonetics. In attempting to address this issue, it is of course important to factor out phonetic characteristics that are not a result of the phonological structure in question, but a result of some other factor, such as those in the preceding discussion. In comparing the durations of simple segments to NC sequences, two issues are particularly relevant to consider—shortening of consonants in clusters and inherent segmental durations.

The expectations about NC duration alluded to in chapter 1 and discussed in more detail below are for NC clusters to be longer than unary NCs. However, it is important to point out that a cluster of two segments should not be expected to be as long as the combined durations of two independent segments. A number of past studies have clearly demonstrated that consonants shorten when adjacent. For example, Haggard (1973) finds that clusters of two segments in English are significantly shorter than the combined durations of the component phones occurring independently, for various places and manners of articulation. Other studies have related this shortening to the "compression effect" observed in some languages, where certain prosodic categories (such as syllable or word) maintain a fairly consistent duration, resulting in increased shortening of each segment for every segment added (e.g. Lindblom and Rapp 1973, Herbert 1975, Vatikiotis-Bateson 1984, Farnetani and Kori 1986). Therefore, while there might be an expectation that an NC cluster will be significantly longer than a single consonant, the ratio will likely not be 1:2 (C:NC), but rather something greater than 1:1 and less than 1:2. There is no defining ratio, however, and it can only be determined, by looking at results across speakers and languages, what the average ratio range is, for a given language or cross-linguistically. As an example, singleton to geminate ratios are observed to have a wide ratio range across languages, with some having small average C:CC ratios, such as 1:1.24 in Swedish, and others having large ratios, such as 1:2.95 in Turkish (Ham 1998).

A second issue relates to the inherent durations of segments. It is well known that consonants exhibit inherent duration differences based upon factors such as place and manner of articulation (see e.g. Lehiste 1970). It is therefore not possible to talk about the typical duration of a "single consonant" in a language; rather, it is important to refer to the average duration of a particular consonant-type, and to make comparisons accordingly. The voicing of obstruents, for example, significantly affects their inherent durations, with voiced consonants typically being shorter than comparable voiceless consonants (e.g. Lehiste 1970, Klatt 1976, Zue and Laferriere 1979). The issue of voicing is particularly relevant for NC studies. Oftentimes, the duration of a voiced NC sequence is compared to the duration of a voiceless obstruent at the same place of articulation. While this may be understandable in light of the fact that many languages with unary NC sequences do not have plain voiced stops, comparing a voiced prenasalized stop to a voiceless stop is not necessarily informative and may result in misleading conclusions.

3.1.2 NC total duration

As briefly addressed in chapter 1, two conflicting claims—that NC clusters are longer than unary segments, and that NC clusters are not longer than unary segments—are found in the literature. In this section, I review the past studies on NC duration. I find, first of all, that data in these studies indicate that the former assertion is true—that NC clusters *are* longer than unary segments, despite claims to the contrary. Second, I find that there is an astoundingly small amount of data on this topic overall, and that regardless of what the previous studies suggest, it is far too premature to make any cross-linguistic claims about NC sequence structure and how it relates to the phonology-phonetics interface, based on the available data. In reviewing these studies, I make reference in some cases to the duration ratio between plain nasals and NC sequences in a language, as this is the comparison found to be most relevant in chapter 5 (discussed in more detail in section 3.2.5). I focus on voiced NC sequences, since there are both unary and cluster examples (as opposed to NC̥ sequences, which can only be clusters, as discussed in chapter 2, section 2.1).

Prenasalized stops

Only a few small studies report the duration of prenasalized stops in languages with the clearest cases of unary NC segments—those where voiced NCs do not contrast with plain voiced stops. One of these studies is of Ndumbea, a language of New Caledonia (Gordon and Maddieson 1999). The authors, analyzing data from six speakers, report that prenasalized stops have essentially the same duration as plain nasals at the alveolar, alveopalatal, palatal, and velar places of articulation. The sequences are longer than plain nasals at the bilabial place, although this is attributed to the different syllabic structures of the compared forms. Hooley (1975) conducted a small study of the prenasalized stops in Buang, a language of Papua New Guinea (and compared them with the clusters in English). He reports that the NC sequences have roughly the duration of single segments in Buang (while they are much greater in English). The data, however, are based on only a single repetition each of two speakers and is generally difficult to interpret.

Perhaps the most frequently cited study in this category was done on Fijian. In recordings of 11 speakers (from three dialects), two repetitions each, Maddieson (1989) finds that prenasalized stops in the language are comparable in duration to single stops. However, the study does not include any data on the duration of plain nasals. As will be seen in the chapter 5, it is the comparison between the duration of plain nasals and NC sequences that proves to be the most relevant in distinguishing unary segments from clusters. Comparisons of voiced NC sequences with plain voiceless stops, for example, the type of comparison made by Maddieson, are less straightforward in what they reveal about NC duration characteristics.

Another study was undertaken on what are described to be prenasalized stops in the Nilo-Saharan language Moru (Burton, Blumstein, and Stevens 1992). Unlike in the above cases, the sequences in Moru do contrast with plain voiced stops. The authors (who are mainly interested in spectral characteristics of the sequences), find that the NC sequences are longer than plain nasals; however, due to the very small amount of data (an uncontrolled recorded corpus from a single speaker) and great overlap between the categories, they conclude that "the duration measures do not systematically distinguish prenasalized stops from either nasals or voiced stops" (133).

NC clusters

There have been several studies that report the duration of clear phonological NC clusters. One of these is Vatikiotis-Bateson's (1984) study of English. Although often cited as an example of NC-cluster shortening, and of how NC sequences are comparable in duration to single segments, the study actually reveals that NC clusters are substantially longer than plain nasals at the same place of articulation. Based on recordings of five speakers (two repetitions each of five forms for each segment or sequence-type), the ratios of plain nasals to corresponding voiced NCs (based upon my calculations of his figures) are 1:1.5 for bilabials, 1:2.3 for alveolars, and 1:1.6 for velars. (The much greater ratio for alveolars must be considered in light of flapped /n/ tokens reducing the duration averages.) Comparisons of the nasals to NC̥ clusters produce even greater differences. Another paper in this category is Adisasmito-Smith's (2004) study of Indonesian. Based upon recordings of three speakers, four repetitions each, she finds that medial NC clusters are significantly longer than plain nasals, an N:NC ratio of about 1:1.6 for the voiced sequences across places of articulation, and an even greater difference for NC̥. She finds similar results (although smaller differences) for what are argued to be the tautosyllabic clusters in Javanese.

Also in the cluster category, I include studies of several Bantu languages. In all of these cases, sequences traditionally described as prenasalized stops have been analyzed by the authors of the studies as clusters. Herbert (1975) reports for Luganda that the NC sequences have longer durations than single segments (although shorter than other clusters). However, no figures are given, and his interest is primarily in vowel length. Maddieson and Ladefoged (1993) conduct studies of Luganda and Sukuma, recording one speaker for each language, and find longer NC than plain N durations in both cases (an N to NC ratio, across places of articulation and word position, of about 1:1.8 for Luganda, and 1:2 for Sukuma, based upon my calculations of their figures). They are particularly interested in how duration may be related to moraic structure in these cases, to be discussed in more detail in chapter 6, section 6.5. Building upon the Luganda and Sukuma data, Hubbard (1995a) conducts a study of Runyambo, and in recordings of three speakers, finds an average N:NC ratio of 1:1.4 (pooling across places of articulation and two prosodic contexts, three repetitions each, based upon my calculations of her figures). Interestingly, a study with one speaker of Lusaami (Marlo and Brown 2003) finds that NC clusters are substantially longer than plain nasals in non-reduplicated forms, but that the NCs shorten in reduplicated forms.

Labial gestures in unary versus cluster NC

Although they make no specific claims about duration, Browman and Goldstein (1986) are often cited as presenting data illustrating that there are no notable differences between prenasalized stops and NC clusters. The authors conduct an articulatory study of labial gestures, examining NC sequences (that they take to be prenasalized stops) in the Bantu language KiChaga and the NC clusters of English, along with plain stops and nasals in each. They claim that in both languages, a single labial gesture is involved in the articulation of bilabial NC sequences (except in the case of initial syllabic NÇ̥ sequences in KiChaga), similar to the plain segments, although they do not make specific claims about relational durations. Maddieson (1989) calls several details of this study into question, including—regarding the English data—that the single segments used in the comparison may actually be ambisyllabic (given that they follow the /æ/ vowel which can only occur in closed syllables), and—regarding the KiChaga data—that the NC is actually bi-morphemic and therefore does not constitute an underlying unary segment. These points, as well as factors related to the very limited scope of the study (only one speaker of each language, only one place of articulation, initial position in KiChaga compared to medial position in English), and particularly the point that the claims are about labial gestures and not necessarily absolute durations (as so often assumed) mean that this study is best viewed as preliminary.[1]

Singleton and geminate NC

As discussed in chapter 2, section 2.1, in addition to unary NCs and NC clusters, there are claims of geminate prenasalized stops. Ladefoged and Maddieson (1986) and Letterman (1997) present some phonetic data on the singleton-geminate contrast. These data will be discussed in chapter 6, section 6.4.1.

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[1] Note that Browman and Goldstein used the same English words as Vatikiotis-Bateson, but the latter did find substantially longer NC clusters than plain segments.

Summary

With the exception of the Browman and Goldstein (1986) study, all of the previous studies appear to illustrate that prenasalized stops are about the length of single nasals, while NC clusters are significantly longer. If this is the case, why is there so much confusion in the literature? Several factors appear to contribute. First, the phonological status of the sequences is often mischaracterized. For example, Downing (2005) cites Hubbard's (1995a) Runyambo data as illustrating that prenasalized stops may be longer than single segments, even though one of the goals of both articles is to argue that the Bantu sequences are actually clusters. Second, comparisons of absolute duration are often made across languages, which is problematic since the languages may simply have different duration characteristics in general, not to mention that the speakers and tokens differ. For example, Maddieson and Ladefoged (1993), in discussing the approximately 100 millisecond Sinhala sequences, state that "the 'prenasalized stops'… are of comparable duration to …English, where word-medial nasal + stop clusters have durations in the range of 90-80 msec" (265). Such a comparison tells us very little in the absence of data on single segments in each language: perhaps all segments are longer for those repetitions of those speakers of Sinhala, or all segments are shorter for those repetitions of those speakers of English. Third, within a language, non-comparable segments are often compared. As mentioned above, in Maddieson's (1989) study of Fijian, the prenasalized stops are said to be of similar duration to single segments, as compared to plain voiceless stops, even though there is not necessarily any expectation that the duration of a voiced complex NC should relate in any direct way to that of a voiceless stop. At the same time, in references to Vatikiotis-Bateson's (1984) study of English, it is often said that the NC clusters are of comparable duration to single segments, presumably comparing the voiced NC sequences to voiceless stops, a misleading and uninformative comparison when the voiced NC sequences are in fact much longer than comparable plain voiced stops and nasals. Fourth, preliminary or limited results are often accepted prematurely. For example, based upon measurements of prenasalized stops by two speakers of Fula, Ladefoged and Maddieson (1986) find a duration range from 45 to 100 milliseconds (ms), across places of articulation. Given this large range, it is clear that numerous factors were not controlled for in this study, affecting the duration of the measured tokens, and therefore that such figures should not be viewed conclusively without further investigation; nevertheless, Burton et al. (1992) cite these figures as illustrating that the prenasalized stops in Moru are of similar duration (an average of 102 ms) to those in Fula.

The final point is the most critical. Regardless of what the above studies might suggest, on the whole they are based on such small amounts of data that no wider conclusions about cross-linguistic NC patterns should be drawn. In Ladefoged's (2003) guide to conducting phonetic fieldwork, he recommends recording at least six men and six women for a given project, and ideally a dozen of each. In addition, given the discussion of the many factors that affect duration, it is clear that the more repetitions one has to work with, the better. Of the above studies, however, the majority use only one speaker and record only one or two repetitions. In chapter 5, it will be clear just how misleading such limited data can be. It is also well understood how segmental duration, in particular, varies widely in accordance with numerous factors presumably unrelated to any specific point under investigation, as previously discussed. Even the precautionary step of placing words in minimal pairs and consistent frame sentences does not rule out all non-relevant factors. Nevertheless, the majority of the above studies make use of words that are not matched with minimal pairs, not necessarily in the same prosodic context, and not uttered in frame sentences.

Of course, Ladefoged's suggestion is an ideal. Constraints of time, funding, and the availability of speakers, all result in studies of smaller scale than most researchers would like. It is not that the above studies are not valuable; on the contrary, they provide us with what little information we do have on this topic, and they are an important step forward in learning more about these sequences. What it does mean, however, is that these studies should be viewed as preliminary, and should not be used to draw any larger conclusions about cross-linguistic NC structure and how it relates to the phonology-phonetics interface.

The present study strives to make a more systematic and substantial contribution, in terms of data, to investigating the larger questions explored here. Based upon the long-held assumption (currently in dispute) that NC clusters are longer than unary NC segments, I formulate the following two hypotheses. There are necessarily two distinct hypotheses, rather than one, since no language has both unary and cluster NC sequences of the same voicing specification, and since comparing durations directly across languages can be misleading.

H1: Unary NC segments are similar in duration to comparable unary segments in a language

H2: NC clusters are substantially greater in duration than comparable unary segments in a language

The hypotheses are purposefully stated in rather vague terms such as "similar" and "substantially greater". The reasons are, first of all, because given inevitable variation, two phones can never be expected to have precisely the "same" duration, and second of all, because it is not yet clear how much of a difference in duration between two phones is an important difference. These issues will be revisited as the duration data are presented in chapter 5. As will be seen, duration data from all four of the languages investigated here overwhelmingly support both of the above hypotheses.

3.1.3 Degree of nasalization in preceding vowels

The claim that vowels tend to be more nasalized preceding a nasal coda than a nasal onset, and therefore more nasalized before a heterosyllabic NC cluster (i.e. N.C) than a tautosyllabic sequence (i.e. .NC or ^{N}C), has been suggested in a variety of languages (see e.g. discussion and citations in Herbert 1986). Few studies, however, have investigated these impressionistic observations with phonetic data. Maddieson and Ladefoged (1993), based upon visual inspection of spectrograms, find that in Sukuma, where the nasal in NC is argued to be partially syllabified in a coda and therefore the preceding vowel is closed, anticipatory nasalization begins about halfway through the vowel. In Luganda, on the other hand, where the NC is argued to be tautosyllabic and therefore the preceding vowel is in an open syllable, there is little or no vowel nasalization. Aside from the fact that these observations are based on recordings of just a single speaker each, there are no comparable data on vowel nasalization preceding plain nasals in these languages; therefore, there is no way to know if the observed nasalization is actually related to syllable structure, or merely reflects language or speaker-specific variations in vowel nasalization patterns. Furthermore, without systematic measurements, acoustic analysis alone is not particularly informative when discussing degree of nasalization. (Interestingly, Herbert 1975 makes the opposite observation about Luganda—that vowels do nasalize before NC, but not before a plain nasal.)

Other studies of vowel nasalization do not appear to support the hypothesis that vowels necessarily exhibit more nasalization in closed syllables. In Cohn's (1990) study of English, French, and Sundanese, using nasal airflow, she finds that vowels in open syllables preceding nasal onsets, compared with vowels in closed syllables preceding nasal codas, exhibit no consistent differences in amount of anticipatory nasalization for multiple speakers of each language. Adisasmito-Smith (2004) also considers anticipatory nasalization in her study of Indonesian and Javanese, using acoustic data. Based upon House and Steven's (1956) observation that vowel nasalization correlates with broader F1 bandwidth, she calculated bandwidth in vowels preceding NC by way of the difference between the amplitude of the first harmonic and first formant (per Hanson 1997), and found little evidence that syllabification of a nasal affects the nasalization of a preceding vowel. In Indonesian, where medial NCs are heterosyllabic, she finds little or no vowel nasalization on a vowel before an NC (in a closed syllable) or before a plain N (in an open syllable). She obtains similar results in Javanese, where vowels preceding both a tautosyllabic NC and a plain N are in open syllables. It is possible that, in the cases of Indonesian and Javanese, the lack of difference is due to a lesser degree of anticipatory nasalization observed more generally in Indonesian languages (see Cohn 1993b).

Despite the questionable nature of anticipatory nasalization as a cue to syllable affinity, it is worthwhile to consider the issue with the present data. Based upon the impressionistic observations summarized by Herbert (1986), and the claims by Maddieson and Ladefoged (1993), all of which suggest greater nasalization before a nasal coda than a nasal onset of a following syllable, I formulate Hypothesis 3.

> H3: Vowels are more nasalized preceding a nasal in the syllable coda than preceding a nasal in the onset of the following syllable

As the airflow results from the four languages in the present study will reveal, anticipatory vowel nasalization is not a cue to the syllable affiliation of a nasal in the languages investigated here. Further, the considerable variation exhibited between speakers, and across the repetitions of a given form for a single speaker, highlight the importance of considering data from multiple repetitions and speakers before making conclusions about a language's phonetic patterns. Although the anticipatory nasalization data did not turn out to be relevant for distinguishing NC-types, other aspects of the nasal airflow data are quite interesting; these results will be discussed in chapter 4.

3.1.4 Preceding vowel duration

The duration of a vowel preceding an NC sequence is often discussed as a possible diagnostic for syllable affiliation. Maddieson (1985), drawing upon a number of studies, argues that closed syllable vowel shortening (CSVS) is a universal phonetic process whereby a vowel is shorter before a coda consonant than an onset consonant. This claim, supported by data from numerous languages (see articles referenced by Maddieson), has led to the hypothesis in NC studies that if a vowel is shorter before an NC than a plain N, the nasal is in coda position, whereas if it is the same length before N and NC, it is in an onset. Maddieson does not specifically discuss NC sequences, however, focusing mainly on vowels closed by geminates in languages with both vowel and consonant length distinctions. Given this, and the fact that there are exceptions to CSVS even among those languages that do fall into the investigated category (see e.g. Letterman 1997 for Sinhala, Ham 1998 for Hungarian), it is not clear how this diagnostic should apply in the case of NC sequences. While shortening before NC may suggest that the nasal is a coda, a lack of shortening will not necessarily suggest that it is in an onset. There are a large number of studies that include data on preceding vowel durations. I focus here on those that specifically examine NC sequences.

Several studies of languages with clear NC clusters find that vowels shorten before an NC sequence, arguably due to the nasal being in coda position, for example in Italian (Farnetani and Kori 1986, Smith 1992). This generalization does not necessarily extend more generally, however, as seen, for example in Vatikiotis-Bateson's (1984) study of English where vowels do not shorten significantly before NC. On the other hand, a few studies of languages with clear tautosyllabic NCs (whether unary or cluster) indicate that vowels do not shorten before NC where the nasal is in an onset, illustrated by Fijian (Maddieson 1989) and Javanese (Adisasmito-Smith 2004).

Some NC vowel duration studies suggest, however, that vowel duration before NC may be a special case. In Indonesian, for example, where NC sequences pattern like other clusters and are thus given a cluster analysis (Lapoliwa 1981), Adisasmito-Smith (2004) finds that vowels *do not* shorten before NC sequences, but *do* shorten before other consonant clusters, including non-homorganic NC sequences. Such results suggest either that the NC cluster analysis is wrong and that the sequences are tautosyllabic (although this is not supported by the phonology), or that there may actually be some sort of phonetic lengthening occurring before NC. Lengthening before NC clusters is also observed, impressionistically, in Johore Malay (Teoh 1988), where, like in Indonesian, there is not otherwise phonological evidence for treating them as tautosyllabic.

By far the most discussed topic regarding pre-NC vowel durations is the lengthening observed before NC sequences in a number of Bantu languages. Many of these languages have phonologically short and long vowels, but the contrast is neutralized before NC where all vowels are long. Often referred to as compensatory lengthening, this lengthening has been one of the key motivations for claiming that NC sequences in these languages are tautosyllabic: the nasal, associated at an early stage of derivation with a coda, is resyllabified in an onset, leaving behind a timing slot or mora that links to the vowel (see e.g. Clements 1986, Hyman 1992, and various other references listed in Herbert 1987 and Downing 2005.) (As mentioned in chapter 1, section 1.3, however, there are alternative theories that do not attribute the lengthening to the syllabification of the NC, e.g. Downing 2005.)

More recently, phonetic studies of Bantu languages have revealed that the situation is more complex. Herbert (1975), in a study of Luganda, finds that vowels do lengthen before NC, but not to the full length of long vowels in the language. These results have been confirmed by subsequent studies. Maddieson and Ladefoged (1993) also find that vowels lengthen before NC in Luganda, to a point near, but not reaching, the full length of a long vowel. They also find that pre-NC vowels lengthen in Sukuma, although only to a point about halfway between the length of phonologically short and long vowels (less than the lengthening in Luganda). They attribute the differences to moraic structure: in Luganda, the nasal loses its entire mora to the preceding vowel and therefore the vowel lengthens considerably, whereas in Sukuma, the nasal shares a mora with the preceding vowel and thus does not receive the full length of the mora. Hubbard (1995b) conducts a study of vowel duration in three other Bantu languages and finds vowels preceding an NC have one of three duration patterns: similar to a phonologically short vowel (CiTonga), somewhere between a phonologically long and phonologically short vowel (CiYao), and similar to a phonologically long vowel (Runyambo). She attributes the difference to the different moraic structures of the nasals. Similarly, Meyers (2005) finds moraic structure to affect the length of vowels preceding NCs in Kinyarwanda. In their study of Lusaami, Marlo and Brown (2003) find the pre-NC vowels to be equivalent in length to phonologically long vowels. (See also Broselow, Chen and Huffman 1997 for general discussion of moraic structure and duration.)

The topic of pre-NC vowel lengthening is a large and complex one, and the cautionary remarks about the phonetic studies expressed in the discussion of NC consonant duration apply in many cases to the above studies as well, primarily given the small amounts of data. For the purposes of this study, the interest is in the diagnostic role of syllable structure independent of moraic structure, which is clearly at issue in the Bantu cases. The best cases to consider are those where syllabicity and moraicity are not conflated, and there is independent evidence for the affect of syllable structure on preceding vowel duration.

Based upon the CSVS predictions and the interest in learning if preceding vowel duration is related to the syllable affiliation of a following nasal, the following hypothesis is formulated for the present study:

> H4: Vowels are shorter preceding a nasal in the syllable coda than preceding a nasal in the onset of the following syllable

In fact, the results of the present study reveal that preceding vowel duration is not a consistent indicator of syllable affiliation of the nasal and therefore do not provide a useful way to address the questions set forth in this thesis. The data are therefore not discussed in the results but are briefly reviewed in the following section.

3.1.4.1 Results- Preceding vowel duration

The vowel duration data collected for the present study of the four languages described in chapter 2, section 2.2, do not support Hypothesis 4. However, since there are no previously published instrumental phonetic studies of any of these languages, I include the complete results in appendix B. In addition, I provide a brief overview of the data in each of the languages here.

Before summarizing the results below, it is important to mention that when considering preceding vowel duration (as when looking at consonant durations), factors unrelated to the subject of investigation may have an impact on the results. For example, the voicing of the consonant following the vowel may have an effect on vowel's duration, as various studies have shown that vowels are longer before voiced consonants than before voiceless consonants (Chen 1970, Keating 1985 and references therein; see also Mitleb

1984 for counter-examples). This effect is most robustly observed for cases where the relevant consonant closes the syllable, and while it has been observed in some cases where the consonant is the onset of the next syllable, this is much less clearly documented. The question of whether or not the voicing has an effect on vowel length even when a nasal precedes the obstruent has not been conclusively determined, to my knowledge. In addition, vowel length is sometimes observed to be compensatory, with longer vowels before shorter consonants, and vice versa (not unrelated to the voicing issue, as voiced obstruents tend to be shorter than voiceless ones). I will not discuss these issues in detail here, but mention that they should be borne in mind when considering the possible impact of nasal syllable affiliation on vowel duration.

Following is a brief overview of the data on preceding vowel duration. Manado Malay and Erromangan are presented first, as these language have both open and closed syllables and therefore H4 can be tested, followed by Tamambo and Pamona which have only open syllables. As there are many durational comparisons that can be made, and contradictory trends are found across speakers, the discussion is necessarily dense, and I refer the reader to specific figures in appendix B for clarification.

Manado Malay

In Manado Malay, NC sequences form heterosyllabic clusters, with the nasal in coda position. Based upon H4, we would therefore predict shorter vowels before NC than before N.

Duration data from a non-NC cluster were considered first. In this set, the /a/ in an open syllable ([sa.ki] 'sick') was compared with an /a/ in a syllable closed by /k/ ([sak.si] ‘witness’). The results reveal that there is little, if any, vowel shortening in a closed syllable in this language (figure B.1). For two of the four speakers for whom results are presented, the average duration values of /a/ show no significant difference between the two contexts, while for two other speakers the difference is significant but small, with only a 12-14 ms average shortening in the closed syllable. Based upon these data, there is no independent evidence for an effect of syllable affiliation on the duration of a preceding vowel, and therefore we would not expect vowel duration to be a reliable diagnostic for syllable affiliation of a nasal in an NC sequence either.

Data on preceding vowels in the alveolar NC set (figure B.2) reveal that vowels are generally longest before /d/ and shortest—or equally short—before /nt/. However, how the average durations of the other sounds fall between these two varies depending upon the speaker, and in general, the differences are very small with a great deal of overlap. This pattern is somewhat different for the bilabials (figure B.3), where vowels before either /b/ or /m/ compete for longest, and vowels before /p/, /mb/, and /mp/ compete for shortest. For the velars (figure B.4), where data from two speakers are considered, one speaker exhibits a tendency for shorter vowels before the NC clusters, but the other shows virtually no duration difference in vowels before any of the sounds. For the NC affricates (figure B.5), interestingly, vowels show a slight tendency to be equal in duration to those before plain nasals, or even longer before the NC cluster than the plain nasal.

While some speakers exhibit a tendency for slightly shorter vowels before the NC clusters at some places of articulation, the data are too inconsistent to view this as support for Hypothesis 4. The tendency for shorter vowels before voiceless consonants appears to be somewhat more consistent. In addition, the vowel length differences do not appear to be compensatory, in that vowels are not necessarily longer before shorter consonants (as can be determined by comparing the vowel duration data with the consonant data in chapter 5).

Erromangan

In Erromangan, the voiced alveolar NC sequence forms a prenasalized stop /ⁿd/; therefore vowels preceding this segment are open. The NC̥ sequences form heterosyllabic clusters, and therefore preceding vowels are in closed syllables. Based upon H4, we would predict longer vowels before /ⁿd/ and the plain consonants than before /mp, nt, ŋk/.

At the alveolar place of articulation, vowels are the same duration before unary /ⁿd/ and cluster /nt/ (figure B.6), contrary to H4, with vowels before plain /n/ having a somewhat longer duration than before both of the sequences, and vowels before /t/ varying in duration among speakers. For the bilabials (figure B.7), vowels before /m/ and /mp/ are the same duration for all of the speakers, while vowels before /p/ tend to be slightly shorter. For the velars (figure B.8), vowels are the same length before all of the sounds--/ŋ/, /k/, and /ŋk/, although E4 actually has shorter vowels before the plain nasal. None of the Erromangan vowel duration data in any way support H4; they do not even exhibit trends in the expected direction.

Preceding vowel duration in Erromangan is clearly not related to the phonological status of an NC sequence, as vowels are not shorter in syllables closed by nasal codas than when in open syllables. In addition, vowel duration does not appear to be related to consonant voicing, as vowels are not necessarily shorter before voiceless consonants than voiced. Further, as can be seen when comparing the vowel duration data with the consonant length data in chapter 5, it is clear that vowel duration is also not compensatory, in that vowels are not necessarily longer before shorter consonants.

Tamambo

In Tamambo, all NC sequences form prenasalized stops, and all vowels preceding NC sequences are therefore in open syllables. H4 does not make any predictions about vowel duration data in Tamambo.

For all of the Tamambo speakers, vowels are generally the same length before N and NC at both the alveolar and bilabial places of articulation (figures B.9 and B.10, respectively), with a slight tendency for marginally shorter vowels before the sequence in the case of alveolars. Vowels before the prenasalized affricate [^{n}dʒ] reveal that vowels are slightly shorter before the sequence than plain /n/ for two speakers (figure B.11), but two other speakers exhibit no difference. Vowels before voiceless /t/ are somewhat shorter than before the other alveolars and the alveopalatal sounds, for four of five speakers, but vowels do not tend to be shorter before the other voiceless segment, /s/.

In general, vowel durations tend to be quite similar before all sounds in Tamambo, with a slight tendency for shorter vowels before the voiceless stop (but not fricative). Vowel length does not appear to be compensatory, as shorter vowels are not found before longer consonants (as can be seen from comparisons with data in chapter 5). H4 cannot be tested in Tamambo, which has no closed syllables.

Pamona

In Pamona, NC sequences form tautosyllabic clusters, and therefore vowels preceding all NC sequences are in open syllables. As stated, H4 therefore does not make any predictions about vowel duration in Pamona.

The same generalizations can be made at each place of articulation about the durations of vowels preceding NC sequences and corresponding plain nasals and stops (figures B.12-16). Vowels tend to be longest before plain nasals and voiced stops, with some variation depending upon the speaker. Vowels tend to be shortest before plain voiceless stops, NC̬ sequences, and NC̥ sequences. However, the gap between these "shortest" and "longest" categories is usually very small (and for some speakers, at some places of articulation, does not exist at all).

There is a slight tendency for vowels to be shorter before longer consonants (the voiceless stops) and clusters (the NC sequences). Not surprisingly, although compensatory, the shortening is not fully compensatory, in that a longer vowel by no means makes up the difference in timing before a shorter consonant, as can be seen when comparing vowel duration to the consonant duration facts in chapter 5. To summarize, H4 cannot be tested in Pamona, as it has no closed syllables.

3.1.5 Phonetic factors- Summary

The preceding discussion provided an overview of the phonetic factors often considered in NC studies—total duration of NC, nasalization of the preceding vowel, and duration of the preceding vowel. I argued that past studies show that there is in fact a duration difference between unary NC segments and NC clusters, with the latter being substantially longer, while the other two factors are less conclusive. I also cautioned against drawing premature conclusions from insufficient data. In addition, I formulated four hypotheses to be tested. I presented an overview of the results for one of them, H4—that vowels are shorter preceding nasal codas than onsets—and argued that it is not supported by the data and does not warrant further discussion. The other three hypotheses will be investigated in chapters 4 and 5.

3.2 Methodology

The primary question under investigation in this thesis is— Are there distinct NC patterns in the phonology, and if so, are these patterns reflected in the phonetics? As argued in the previous section, although there have been attempts to address the second part of this question in the phonetic literature, there are not yet clear answers. While some of the difficulty is likely due to questionable phonological assumptions, a major factor is the lack of sufficient phonetic data. In order to address this question and contribute a more reliable and systematic set of data to the discussion, I decided to undertake phonological and phonetic studies of four Austronesian languages. In the remainder of this chapter, I provide background information on these studies, as well as present the methodology used in the data collection and analysis.

3.2.1 Choice of languages

My goal at the outset was to collect data from languages representing as many NC sequence types as possible. This ideal was tempered by two factors—the inability to know definitively what type of NC sequences a language has until fieldwork begins (though past studies are of course a useful starting point in this regard), and constraints of time and funding. Ultimately, I collected data on four languages, each with a different NC sequence pattern.

As mentioned in the introduction to the thesis, I chose to focus my research on Austronesian languages, both because they are known to contain an interesting variety of NC sequences, and because I have somewhat more background working with languages in this family than in others. I had been studying Indonesian for several years with the goal of later using it as a contact language to conduct research on the lesser-studied regional languages, and therefore I chose to undertake fieldwork in the country. I was also interested in studying one or more Oceanic languages, given that they are known for containing clear cases of prenasalized stops. For this purpose, I chose Vanuatu in the South Pacific, due to the large number of potential research languages in the country, as well as the desire to highlight the status of endangered languages in this small but linguistically diverse region.

Thanks to the receipt of a fellowship from the Fulbright-Hayes Doctoral Dissertation Research Abroad Program, as well as a fieldwork grant from the Southeast Asia Program at Cornell University, I was able to undertake fieldwork in both Indonesia and Vanuatu from November 2003 through July 2004 (approximately four and a half months in each country), as well as a follow-up trip to Indonesia for two months in the spring of 2005. In Indonesia, I sought to study a language of Central or Southeast Sulawesi, given their interesting NC patterns (as discussed previously). Due to my familiarity with North Sulawesi from a previous research trip and my contacts in the region, I chose to base myself in Manado and work with displaced speakers there. A search for speakers conducted after arriving yielded a sizable community of Pamona speakers, and I therefore chose to work on this language. During my return trip, I conducted a study of Manado Malay, the regional variety of Indonesian spoken in the area, as an example of a language with clear NC clusters.

In Vanuatu, I limited my possible languages of study to those that had already been well-described, to assure that I would choose languages with the desired NC patterns. After a search for speakers upon arrival, I ultimately chose to work on Tamambo (described by Jauncey 1997), a language with a series of voiced prenasalized stops, and Erromangan (described by Crowley 1998), a language with evidence of both voiced prenasalized stops and NC̥ sequences. These studies were conducted in the capital, Port Vila, where I was based; I did nevertheless spend time on the island of Malo, where Tamambo is spoken. In addition to my studies of these languages, I completed a project for the Vanuatu Cultural Centre. As a part of the National Education Initiative to promote use of vernacular languages by children, I created several small reading booklets in each of the two languages for use in the primary schools.

3.2.2 Interviews

For the initial work on each language, I met with two native speaker consultants independently, one male and one female, three to five days a week for one to two hours per meeting, over a period of two to three months. The purpose of these meetings was to build a basic grammatical sketch of each language with a focus on the phonology. This was achieved through elicitation tasks beginning with basic words and phrases and building up to stories and longer stretches of spontaneous speech. We also worked together to compile wordlists for the later recordings. These primary speakers then became my assistants for the recordings of additional speakers, helping me with various tasks (such as holding cue cards), but largely serving to make the new speakers feel comfortable in the presence of a foreigner or assuring that cultural taboos were not violated (for example, by having a male assist with tasks involving physical contact with another male, such as adjusting a headset microphone or airflow mask).

These additional speakers who joined the project at a later point met with me for one to two preliminary meetings. The purpose of these meetings was to gather personal information on a speaker's linguistic background and to do some basic elicitation in order to determine a speaker's appropriateness for the study. Additionally, I went over the complete wordlist with each speaker to ensure that all of the words were familiar, and in some cases I made changes to the wordlist based upon their responses. I also described the recording process and familiarized speakers with the equipment. These preliminary meetings were followed by two recording sessions each, one acoustic and one aerodynamic.

3.2.3 Subjects

The Manado Malay subjects are all native speakers of the Manado variety of Bahasa Indonesia (the official language of Indonesia) originally from the city of Manado, from neighborhoods in the Bahu area. All of the speakers have some degree of fluency in the more "standard" variety of Indonesian, as heard in the media and used in government, education, and formal business. However, although all of these speakers can code-switch to some degree when necessary, none felt confident in their abilities in the standard dialect and, when asked if a certain word or phrase they used was "Bahasa Manado" or "Bahasa Indonesia", many were not sure how to respond. These speakers were chosen, in part, due to their limited exposure to the standard variety and limited use of it on a daily basis. Although all of the speakers received some education in “formal” Indonesian at school, none received any post-secondary education, and none worked in an environment where a more formal variety of the language was necessary, thus limiting their exposure to and use of any dialects other than Manado. Ten speakers were recorded for this project, five women and five men, all between the ages of 20 and 36. The language of communication for the project was Bahasa Indonesia.

The Pamona subjects are all native speakers of the dialect spoken in Tentena village, their place of origin, in Central Sulawesi. All are bilingual in Bahasa Indonesia, and none is fluent in a third language. At the time of the recordings, the speakers all lived in the city of Manado in North Sulawesi, having moved there to attend university or accompany a spouse, one month to four years earlier; all had plans to return to Central Sulawesi at the end of their tenure in Manado. (Two speakers had also lived in Manado for several years as high school students, then returned to Tentena for a few years before moving back to Manado for college.) Fieldwork was conducted with these speakers in Manado, rather than in Central Sulawesi, due in part to political conflicts in the Tentena region. Although they use Bahasa Indonesia as their primary language of communication in Manado, all continue to use Pamona on a daily basis when interacting with other Pamona speakers. Seven Pamona speakers were recorded for this project, four men and three women, all between the ages of 20 and 38. Additionally, two elderly speakers were also recorded, though their results were not included in the final analysis. The language of communication for the project was Bahasa Indonesia.

The Tamambo subjects are all native speakers of the language, originally from the western half of the island of Malo. They are all from villages within about 20 minutes walking distance from Avunatari mission (including Jingotano, Avunambahura, Avunareo, Avunatavoa, Avunavae, and Amambwea). All are bilingual in Bislama, the English-based vernacular creole which serves as the national language, and most also have some degree of competency (in several cases quite limited) in either English or French, depending upon their level and language of education (as all formal schooling in Vanuatu takes place in one of these two languages of the former colonial powers). At the time of the recordings, the speakers all lived in the nation's capital of Port Vila, having moved there two to eight years earlier, in most cases to find work. (About half had also spent a few years attending school on another island, usually Santo, a larger island just north of Malo.) Although they frequently use Bislama in Vila, all of them continue to speak Tamambo on a daily basis as they live and work in close proximity with others from Malo. Seven speakers were recorded for this project, four women and three men, all between the ages of 20 and 38. The language of communication for the project was a combination of English and Bislama.

The Erromangan subjects are all native speakers of the language, originally from the southeastern region of Erromango island, from the villages of Umponlong (Happy Lands), Unorah (South River), Potac (Ipota), Pontutu and Antioch. All are bilingual in Bislama, and most also have some degree of competency in either English or French, depending upon their level and language of education. About half of the speakers had previously studied or worked in areas of Erromango other than their home villages, and two had attended school for a short period on the closest island to the south, Tanna. At the time of the recordings, all of the speakers lived in the nation's capital of Port Vila, having moved there one month to thirteen years before, either to find work or to visit family. Although they frequently use Bislama in Vila, all continue to use Erromangan on a daily basis as they live and/or work in close proximity with other Erromangan speakers. Seven speakers were recorded for this project, three women and four men, between the ages of 23 to approximately 45 (several of the older speakers not being sure of their birth dates). The language of communication for the project was a combination of English and Bislama.

As will be seen in chapter 5, not all of the recorded speakers were included in the final analysis. For each language, there were several speakers whose data were difficult to label. Given the importance of very accurate segmental boundaries for the duration data, only the speakers with the most straightforward data, in terms of ease of labeling and analysis, were chosen. Ultimately, data from six speakers of Manado Malay (identified with the labels M1-M6), six speakers of Pamona (P1-P6), five of Tamambo (T1-T5), and four of Erromangan (E1-E4), were included in the analysis.

3.2.4 Wordlists and frame sentences

Since previous studies often suffer from a lack of data that can be reliably compared, it is worth spelling out how factors that are not under investigation might be controlled for, and therefore I include this discussion of the choice of wordlists and frame sentences. There were two primary goals in preparing the wordlists for the recordings. First, I wanted to have examples of each NC-type in the language, meaning the NCs of each place and manner of articulation (the latter encompassing only stops and, in some cases, affricates).

Many past NC studies have considered the sequences at only a single place of articulation, and therefore it remains unclear whether or not place may affect the timing comparisons. For each of the four languages, there are NC stop sequences at the bilabial and alveolar places of articulation. Pamona, Manado Malay, and Erromangan also have velar NCs; Tamambo, Pamona, and Manado Malay also have alveopalatal NC affricates; and Tamambo also has a labialized bilabial NC sequence. Both NÇ̬ and NÇ̥ sequences, where available, were recorded.

Second, I placed all NCs in minimal, or near minimal sets. As is well understood in phonetic data collection (though not always practiced), when investigating phonetic properties such as duration, it is very important to place the token words in minimal (or as close to minimal as possible) sets. Many factors affect the character of segments, including the identity of preceding and following sounds (their place, manner, voicing, sonorancy, etc.), stress placement, and larger prosodic structure; some of these factors were discussed in section 3.1.1. The sets took the following form in each language (the differences due to the presence or absence of plain voiced stops), at each place of articulation, and in both initial and medial position where possible.

- Tamambo: N, Ç̥, NÇ̬
- Erromangan: N, Ç̥, NÇ̬, NÇ̥ (the NÇ̬ being available only for alveolars)
- Pamona: N, Ç̬, Ç̥, NÇ̬, NÇ̥ (where possible, the same set was used across the entire group; otherwise, separate sets were collected for the NÇ̬ and NÇ̥ sequences)
- Manado Malay: N, Ç̬, Ç̥, NÇ̬, NÇ̥

The ideal in creating minimal sets is to have the words be identical in form except for the change of target sound. Whenever possible, such sets were created, but when this was not possible, the following guiding principles were used, referring specifically to medial sets, usually of the form $C_1V_1\underline{\mathbf{NC}}V_2$:

- Words have the same number of syllables.
- Syllables in each word have the same structure. (This was not always possible in Erromangan, where occasionally one member of a set has a final coda while the other do not.)
- Words have the same stress pattern.
- Preceding C_1 and V_1 are identical across the set.
- In at least one of the sets for a form, C_1 is a stop—usually /t/—to increase segmentation accuracy. (This is not always possible in Erromangan, where the majority of words begin with /n/.)
- In at least one of the sets for a form, V_1 is /a/—to increase segmentation accuracy.
- Words are native, or in exceptional cases, word is a nativized borrowing for which there is no native word. (For example, *buku* 'book' a borrowing from Indonesian, was used in the Pamona list; there is no Pamona word for 'book'.)
- All of the speakers know and are familiar with the words; or, in exceptional cases, a majority of speakers know the word and introduce it to those unfamiliar with the term. (For example, *ngaru* in Pamona refers to a type of dance no longer commonly practiced; the speakers who were familiar with the dance explained it to those who were not.)
- Words are monomorphemic (though bimorphemic words were also collected, where available, for comparison).
- Words are ideally of the same part of speech; this was usually not possible.
- Proper names are avoided; this was not always possible in Pamona.
- Two or three different sets for each NC type were recorded, to ensure that the phonetic results for an NC are representative and not due to some idiosyncratic character of a particular word.

For initial sets, the same basic principles, where relevant, were applied. As these sets were harder to construct, however, especially in Pamona, some of the sets are less ideal.

Construction of the wordlists was challenging. For Tamambo and Erromangan, the task was made considerably easier due to good, recent dictionaries (Jauncey 1998 and Crowley 2000, respectively). Even in these cases, however, sets could be hard to find, or speakers might not know a particular word or may pronounce it differently than indicated. For Pamona, although I had several photocopied pages of the NC words from a Dutch-Pamona dictionary compiled prior to 1928 available to me while in the field (Adriani 1928), the primary speakers were unfamiliar with the vast majority of the forms (possibly due to differences of generations and dialects). A dictionary of Manado Malay (Salea-Wartou 1985) was too small to be of value for this task (and a more recent dictionary—Warokka 2004—was not available at the time). For Pamona and Manado Malay, in particular, a great deal of time was devoted to wordlist construction. I searched for pairs based upon all of the NC tokens that arose during routine elicitations, systematically "created" words with letters on flashcards and asked speakers if the words existed in the language (not very fruitful), and in some cases trained the primary speakers to look for minimal pairs, to varying success. The ultimate lists, consisting of about 60 forms in each of the languages, were randomized (by a shuffling of cards). Not all sets were used in the analysis.

Placing words in frame sentences is an important control of prosodic context, and also to aid in segmentation of initial and final segments. There were two goals in creating frame sentences for this (as for most) studies. First, it was important to find a sentence that would work for all forms, across parts of speech. Phonetic studies often accomplish this by using sentences such as "Say ______ now". In Pamona and Manado Malay, use of such sentences was possible, though a great deal of discussion was necessary with some speakers to assure that they were comfortable with this somewhat odd construction. In Tamambo and Erromangan, the primary speakers found this construction far too unnatural (i.e. no one would ever say "Say 'to jump' now"). In these cases, we looked for scenarios that the speakers could find plausible. In Tamambo, the result was "I wrote _______ today", as speakers could visualize a single word written on a page, as if someone were learning to write. In Erromangan, the result was "The baby said _______ today", as speakers could imagine a small child, just learning to speak, mimicking individual words spoken by a parent, even if the word is not generally uttered out of context.

The second goal was to construct frame sentences with the following phonetic form:

- Sound immediately preceding token word is a vowel (as most token words began with C).
- Sound immediately following token word is a consonant (as most token words ended in V; this was not possible in Erromangan, where all candidate words started with a nasal, and therefore a vowel was chosen).
- Sounds immediately preceding and following token word are not nasals or nasalized (to avoid interference with nasal airflow readings).

In some cases, the semantic and phonetic goals were obviously in conflict. The resulting frames were:

(3.1)

Tamambo:	*Ku hare* _____ *tovona*	'I write _____ today'
Erromangan:	*Nalau amangku* _____ *ire*	'The baby says _____ now'
Pamona:	*Manto'o* _____ *ja se'i*	'Just say _____ now'
Manado Malay:	*Cumu jo* _____ *skarang*	'Just say _____ now'

3.2.5 Acoustic data- Recordings, analysis, and data presentation

Recordings

The audio recordings were made with a Marantz PMD 670 digital recorder and a Shure SM-10A headset microphone. The recordings were conducted in relatively quiet areas with efforts to reduce background noise as much as possible. Sound-proof facilities were not available.

The speakers of each language were asked to recite the wordlist of approximately 60 target words in their language, with fillers at beginning and end, each in a frame sentence, a total of ten times (the same order of the list each time). At the end of each repetition of the wordlist, the speakers were asked to take a break for however long they felt necessary before beginning the next repetition. Breaks ranged from less than one minute to ten minutes. The exact recording procedures varied slightly for each language, as described below.

For the Pamona recordings, the frame sentence was written out on a large piece of paper and placed in front of the subject. Each of the target words was written on a note card. An assistant sitting in front of the speaker revealed one target word at a time, and the subject recited the frame sentence, inserting the target word. The assistant then revealed the next card and the subject repeated the new sentence, and so forth. Having an assistant control the cards, rather than having the speakers read from a list, was an attempt to control their speech rate and discourage increasingly rapid pronunciation.

For the Tamambo and Manado Malay recordings, speakers repeated, rather than read, the target words. In both cases, the subjects memorized the frame sentence, and an assistant—also a native speaker of the language—read each target word, with the subject repeating the word in the frame sentence.

For the Erromangan recordings, an assistant was not always available for the recordings, and therefore one native speaker was initially recorded reading each of the target words. The subjects, who had memorized the frame sentence, heard each recorded word one at a time, followed by a Bislama translation by the researcher, and then repeated the frame sentence inserting the target word. The reason for including the Bislama translation was to clarify the recorded words, since some of the words, being phonologically quite similar, were hard to identify out of context without the benefit of a native speaker pronouncing the words. (Despite these controls, some of the forms appeared to have been confused and therefore were not used in the analysis, as explained in chapter 5, section 5.5.)

Labeling

The audio data were segmented, labeled, and analyzed using Praat speech analysis software (Boersma and Weenink 2005, various Macintosh versions up to 4.2.3). As each original audio file contained approximately 60 sentences (one full repetition), the files were first segmented, with each sentence saved in a separate file for ease of later analysis. Labeling then proceeded as follows. A Pratt labeling script opened each token sentence displayed as both a waveform and spectrogram, while providing two interval labeling tiers underneath. The first tier was used to code segment boundaries, and the second was used to code closures and bursts. On the segment tier, labels were placed at the beginning and end of each segment in the target word, as well as at the beginning and end of a specified portion of the frame sentence. On the closures tier, labels were placed at the onsets and offsets of stop closures, aspirations, and bursts. (Determinations of label placement will be discussed shortly.) The resulting intervals on both tiers were then labeled with a code letter in accordance with their type/position.

For example, figure 3.1 below is a token of *Manto'o tampa ja se'i*, 'Say place now' from Pamona. In the target word, /tampa/, each segment is labeled on the first tier (**a**= consonant 1, **b**= vowel 1, **c**= nasal, **d**= consonant 2, **e**= vowel 2), as is a specified portion of the frame sentence, /ntoʔo/ (**f**= frame). (In token words without one of the segment-types, the relevant label simply does not appear, for example, there is no nasal, and therefore no "c" label in *tapa*, 'to cook with smoke'.) On the closure tier, the closures and bursts in the stops /t/ and /p/ are labeled (**w1** or **w2**= closure 1 or 2, **x1** or **x2**= burst 1 or 2). (Due to the small size of the image, it is not possible to see the 'x' labels.)

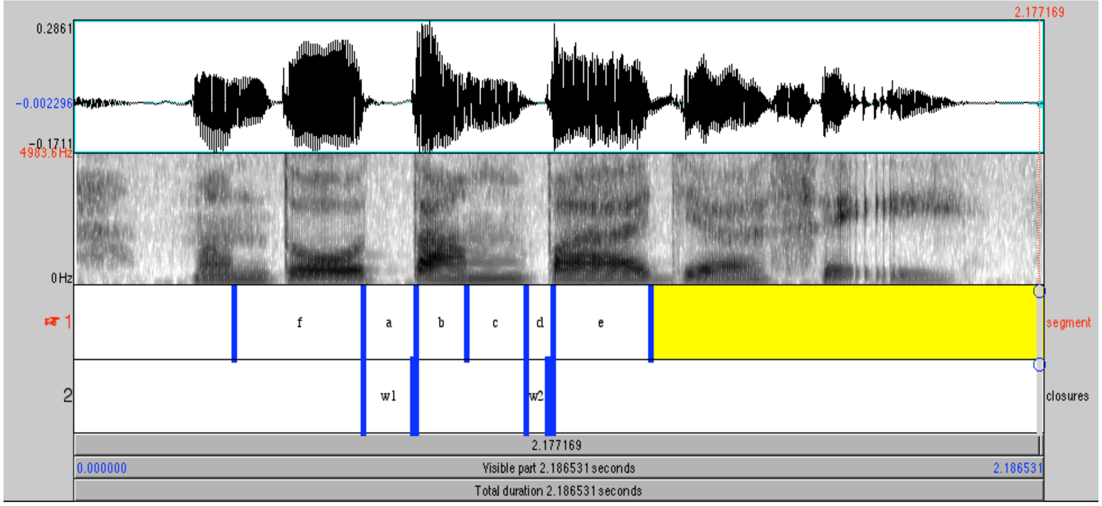


Figure 3.1: Labeled token of P6's third repetition of *Manto'o tampa ja se'i*, "Say 'place' now"

Determinations of label placement were as follows. *Vowels* were segmented from the onset to offset of F2, *nasals* from the end of preceding vowel F2 to the onset of the following vowel F2 or end of nasal formant before a consonant, *consonant closures* as the offset of preceding vowel F2 or end of preceding nasal formant to the sudden spike in intensity of the release burst, and *consonant bursts* as the onset of sudden spike in intensity to the onset of the following vowel F2.

In most cases, label placement was easy to determine, given that token words were selected where possible to contain segments with the clearest identity in spectrograms. If a token contained any segments that were very difficult to label, then the token was not included in the analysis, as incorrect labeling could have serious effects on the duration results. If a token contained a segment that was somewhat difficult to label, but where possible error was believed to be no more than ten milliseconds, the token was included in the results; however, detailed notes were kept in these cases so that if a token's measurements appeared aberrant when viewed in the light of the whole of the data, it could be reevaluated. In some cases, an entire set of a data by a speaker was excluded from the results due to that speaker's tokens being particularly difficult to label. Across the languages, the velars offered the most challenges, with difficulties identifying boundaries between velar nasals and adjacent vowels (perhaps due to the fact that the velar nasals are more acoustically similar to vowels than nasals at other places of articulation, see e.g. Ohala 1975). Therefore, there are fewer speakers and repetitions included in the graphs for this place of articulation than the others. The data on voiced affricates in Pamona and Manado Malay have also been excluded due to considerable labeling difficulties, in particular concerning the division between the fricated release and vowel onset.

Choosing a portion of the frame sentence to label was difficult, due to the fact that some speakers greatly reduced certain syllables at the beginning and/or end of the frame. Originally the intention was to compare the duration of a constant portion of the frame sentence with the duration of the target sounds across all of the tokens, to ensure relative stability of speed across repetitions. Ultimately such measures were not used systematically, a result of labeling difficulties with the frame (for reasons cited above). In addition, spot checks on the clearer cases did not necessarily reveal a predictable relationship between the speech rate of the frame and that of the target word (i.e. sometimes a fast repetition of the frame was paired with a slower and more carefully enunciated target word, and vice versa). Instead, tokens that were extremely and uncharacteristically fast or slow (based upon impressionistic observations) were excluded from the data, and the absolute values of all remaining tokens were included in the analysis.

Analysis and data presentation

A Praat script was written for the project to calculate duration figures for all of the labeled segments. Analyses were then undertaken in SPSS and Excel, and the duration averages and ranges were determined, over the ten repetitions, for each segment in a target word for each speaker. These figures were then compared across the forms in the minimal set. (For example, the duration average and range for the /m/ in /ta**m**a/ 'father' was compared to /mb/ in /ta**mb**a/ 'to bump into' for each speaker of Tamambo.)

Duration studies often report only average values over a number of tokens. Such figures can be very misleading when discussing duration, however, for reasons previously discussed. A particularly long or short token in a set may throw off the average, giving a false impression of the value of the entire category. Further, a set of data with widely ranging values—which may reveal something important about the variability allowed for a certain token—will be obscured by considering only the mean; additionally, distinctive means may result even from strongly overlapping values. For these reasons, the primary data in this study are presented in box plots. Box plots display the range and median together, allowing a reader to quickly understand the normal range of values for a token, and to identify if a particular value is typical or falls out of the expected range. With such a display, outliers are identified as such and do not need to be excluded from the graphs, allowing the reader to identify how stable or unstable a category is, to understand the kind of variability observed in the data, and decide for him/herself whether the outliers contain relevant information. Figure 3.2 below contains a sample box plot, with parts labeled, to guide the reader in understanding the plots to follow in chapter 5.

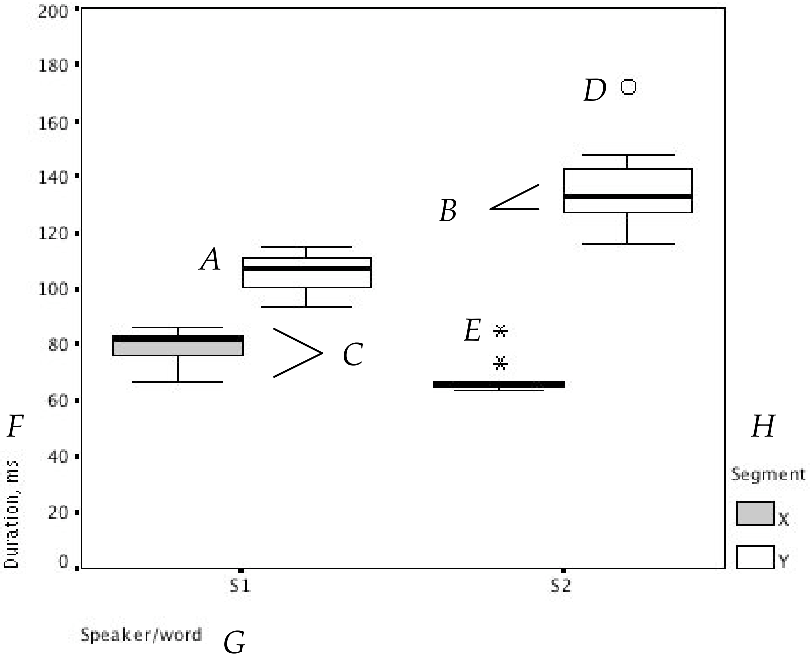


Figure 3.2: Sample box plot with parts labeled. A=median value; B= interquartile range; C=range of all non-outlying data (to at most 1.5 times the IQR); D=mild outlier, falling within 1.5 to 3 times the IQR away from the median; E=extreme outlier, falling beyond 3 times the box width away from the median; F=duration in ms; G=speaker labels; H=segment labels

The sample box plot above contains data for two hypothetical speakers, S1 and S2, displayed along the horizontal axis. The gray boxes for each represent the duration data for segment X, while the white boxes represent the duration data for segment Y, with duration in milliseconds (ms) represented along the vertical axis. A black line in the middle of a box represents the median value across the tokens; for example, S1's median value for X is 82 ms. The range of a box represents the interquartile range—IQR (or middle 50 percent of the data); for example, this range for S2's Y tokens is from 122 ms to 142 ms. The range covered by the whiskers represents all of the non-outlying data (or 1.5 times the IQR from the end of the box); for example, S1's X tokens have a range of 68 ms to 86 ms. Circles represent mild outliers, or those points falling between 1.5 to 3 times the IQR; for example, S2's Y data contain one mild outlier at 172 ms. Asterisks represent extreme outliers, or those points falling more than 3 times beyond the IQR; for example, S2's X data contain two extreme outliers at 73 ms at 85 ms. The number of tokens represented by each box is not indicated on the plot itself, but is always out of ten unless otherwise indicated in the figure label.

When presenting plots that include duration data of NC sequences, the total duration value over the entire sequence (both nasal closure and oral closure and burst) is reported in a single box, as the interest is in comparing sequence duration with duration of corresponding plain consonants. (Similarly, closure and release are combined in the total duration of voiceless obstruents.) In order to see the duration of the component parts of the sequences, bar graphs are also included to illustrate certain portions of the data, as illustrated in figure 3.3 below.

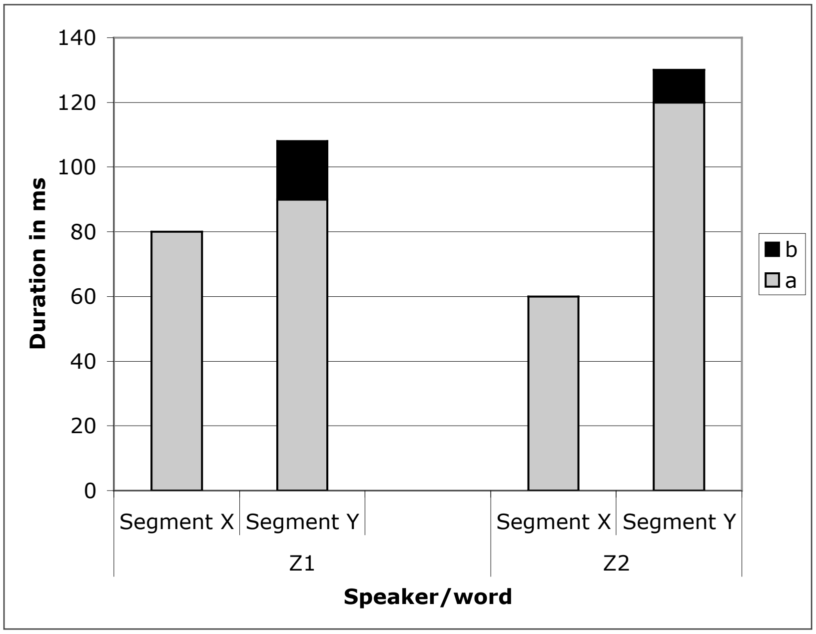


Figure 3.3: Sample bar graph displaying average duration values for the component parts of segments X and Y for two speakers

This sample bar graph contains the same data as the above box plot. With this graph, it is possible to see the how much of the total duration of segment Y is composed of parts "a" compared to "b". (For example, "Y" could be a voiced NC sequence, with "a" representing the nasal closure duration and "b" the oral release.) Even though the average duration values can be determined from the bar graphs, comparative durations will only be discussed in relation to the box plots; the single purpose of the bar graphs is to display the relative durations of the component parts of NC sequences and voiceless obstruents.

In order to characterize the duration of NC sequences, relative comparisons will be made between the duration of the NC and other segments for each speaker of each language. As will be seen in chapter 5, the comparison found to be most relevant for the present study is that between a plain nasal and an NC sequence. This durational relationship will be expressed throughout chapters 5 and 6 in terms of the ratio N:NC. For example, if a speaker has an average /n/ duration of 80 ms and an average /nd/ duration of 80 ms, the N:NC ratio would be 1:1. If a speaker has an average /n/ duration of 80 ms and an average /nd/ duration of 120 ms, the N:NC ratio would be 1:1.5. By using these ratios, it is possible to compare the differences across speakers and languages, without relying on potentially misleading absolute duration averages.

3.2.5.1 Measures of difference

When making claims about duration differences, it is important to have some way of defining these differences; however, it is not clear, when discussing phonological structures, how this should be done, or even if there is one approach that can apply to all situations. Here I briefly discuss statistical significance and Just Noticeable Difference.

If making a claim that a group of NC clusters are longer than a single segment, it is of course important that this difference be statistically significant. However, even a statistically significant difference is not necessarily sufficient if the discussion is about phonological timing. For example, if the duration of a group of plain nasal tokens are an average of 80 ms, while a group of NC cluster tokens are an average of 88 ms, even if the difference is significant, it does not necessarily mean that it is sufficient to indicate a phonological unary-cluster distinction. (Likewise, if those same figures refer to a plain nasal and a unary NC, it does not mean that the duration difference is large enough to indicate that the unary NC is longer than the plain nasal in any relevant sense). Statistical significance will be indicated for the most relevant comparisons in chapter 5, but it will not be discussed in detail. Significance was calculated using two-tailed t-tests and is identified at three levels: p≤.001, p≤.01, p≤.05. Significance was not calculated across speakers, since this can have the same misleading effect as averaging across repetitions, and it was not be calculated across places of articulation, since the different places reveal different patterns. (Therefore, even when statistical significance is discussed, the small amounts of data being compared will reduce the meaningfulness.)

Another measure of difference, Just Noticeable Difference (JND), is a minimum measure of how different two entities need to be (along various parameters) in order for the difference to be perceivable (see e.g. Lehiste 1970). Klatt's (1976) estimation that the JND for duration is about 25 ms is generally accepted. However, it is also not clear that JND is relevant to a discussion of phonological NC duration differences. Since unary and cluster NCs do not contrast, a perceivable duration difference is not necessary to distinguish these sounds from one another (unless a language has the sort of singleton-geminate NC contrast observed, for example, in Sinhala and Fula.) The issue explored in this thesis is how the phonological patterns are reflected in the phonetics, which is different from the question of contrast, and one for which JND is not necessarily informative.

The duration differences in chapter 5 will be discussed in relative terms. When comparing NC sequence duration with plain segments, the full range of data is provided so that readers can determine for themselves which differences appear important and which do not. As will be seen, when NC clusters are longer than single segments, in most cases the difference is so great that it far exceeds typical thresholds of statistical significance as well as

JND. When unary NCs and plain segments, which are generally similar in duration, are compared, even when the sequence is significantly longer, the difference is not nearly as great as it is in the cluster languages.

3.2.6 Airflow data- Recordings, analysis, and data presentation

Recordings

The aerodynamic data were gathered using a Scicon MacQuirer 516 airflow device. The unit connects to a computer (in this case, a Macintosh laptop running OSX) via a USB port and is then operated with MacQuirer software (version 8.9.1). Two masks, one to collect oral airflow and the other to collect nasal airflow, each attach to a transducer in the transducer interface box, which in turn connects to the main unit, as seen in figure 3.4 below. There is also a small microphone positioned in the interface box.

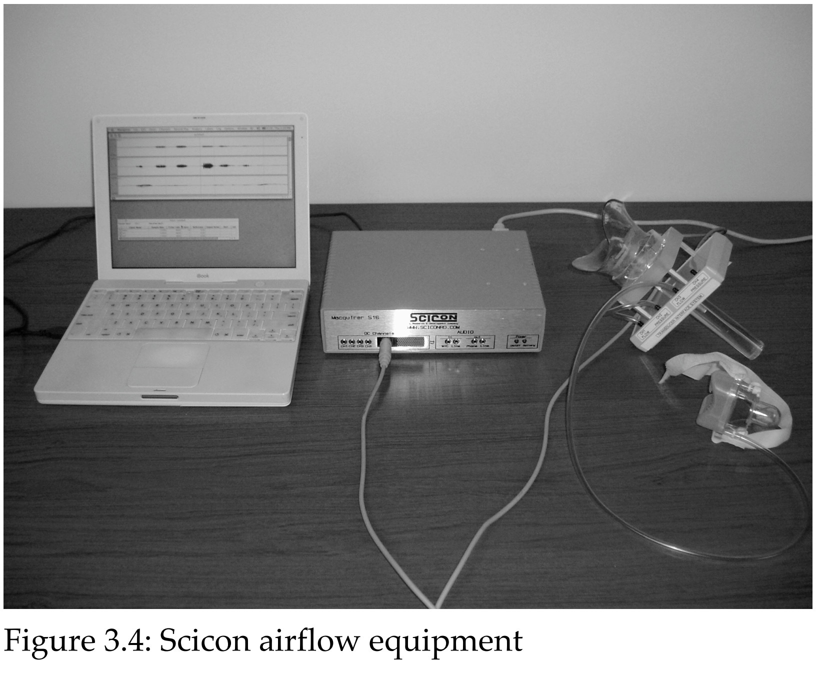


Figure 3.4: Scicon airflow equipment

Figure 3.5 illustrates a speaker demonstrating use of the equipment. The speaker holds the oral mask in place with a handle, directing pressure up towards the face until a complete seal is formed around the mouth. In cases where speakers' faces were too small to create a seal with the mask, layers of foam weather stripping were added to the relevant edges of the mask until such a seal could be formed. The nasal mask fits over the nose and attaches to the head with an elastic strap. In some cases, speakers could feel a small amount of air escaping from the top of the mask near the eyes. For these speakers, an assistant stood next to the speaker and applied extra pressure to the top of the nasal mask, allowing for a complete seal to be formed. When fitted properly, the presence of the oral and nasal masks does not noticeably interfere with a speaker's normal speech. A simultaneous acoustic signal is recorded via the microphone in the transducer interface box.

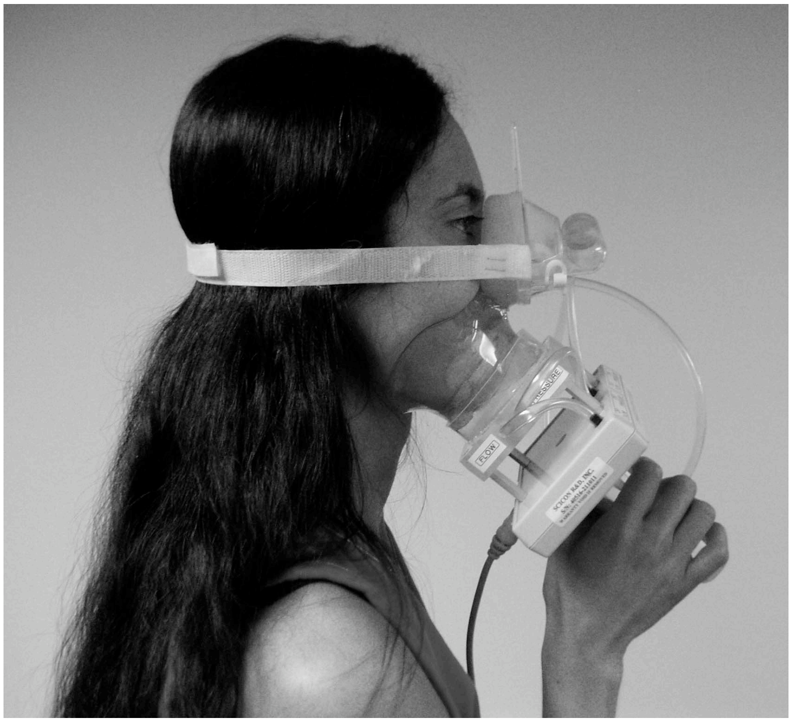
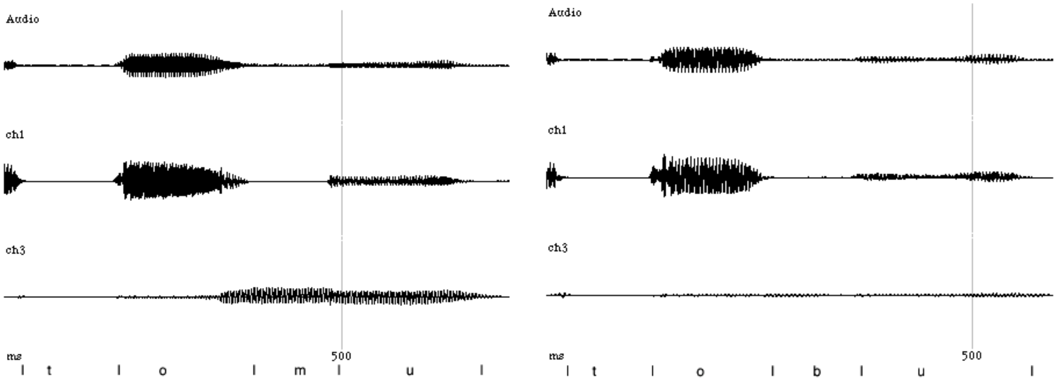


Figure 3.5: Speaker demonstrating use of Scicon airflow equipment

For Pamona, Tamambo, and Erromangan, the standard equipment set-up, as described above, was used. In the case of Manado Malay, however, some changes were necessary. During the fieldwork session, the nasal airflow transducer quit working. Therefore, the nasal mask was attached to the oral transducer. This means that no oral airflow was collected for these speakers, since there was only one working airflow transducer in the unit, allowing recording of only one airflow channel at a time. The airflow recording procedures were the same as those used for the audio recordings, as discussed above, except that speakers repeated the wordlist five, rather than ten, times.

The output of the airflow recordings is data in three channels—audio, oral airflow, and nasal airflow, as seen in the following figure of the Pamona words /tomu/ ‘to meet’ (a) and /tobu/ ‘to gather’ (b):



(a) (b)

Figure 3.6: Data collected with MacQuirer for a token of P6’s /tomu/ (a) and /tobu/ (b) including audio, oral airflow (in ch1) and nasal airflow (in ch 2)

The primary interest in these data for the present study is in the nasal airflow channel (channel three). The nasal airflow data provide an indirect indication of velum position: when the velum is lowered during the articulation of a nasal sound, air escapes from the nasal passage and is thus registered as airflow in channel three. Huffman (1989) and Cohn (1990) discuss some limitations of using airflow data, although none that has a significant bearing on the issues explored here. Although nasal airflow data are sometimes filtered to factor out vocal fold vibrations during voiced segments and facilitate visual inspection of the data, technical limitations prevented such filtering in this case; therefore, raw nasal airflow data will be presented (following Gerfin 1996). Finally, although aerodynamic data are normally calibrated in order to quantify the amount of flow (in milliliters per second), it was not possible to get stable calibration figures for the Scicon unit used to collect these data, and therefore the data have not been calibrated. Given that the interest in this study is in the relative amounts of airflow between different word pairs, the lack of quantification does not pose a problem.

Labeling

Each original airflow file contained approximately 60 sentences. These files were first segmented and each sentence was saved individually. The target sentences of interest were then opened individually, and spectrograms were produced from the audio channel, in order to aid in labeling. Label placement was determined in the same manner as for the audio files, as discussed in section 3.2.5 above. Airflow files were labeled more selectively than audio files, limited to three speakers and three repetitions (repetitions two through four) for each language, with additional speakers and repetitions included if deemed necessary for characterizing the data. An example of the labeling is in figure 3.7 below, a token of the Pamona word /tampa/ ‘place’. With the aid of the spectrogram, labels are placed on the nasal flow channel.[2] When doing the actual labeling, images were zoomed for closer, more detailed inspection.

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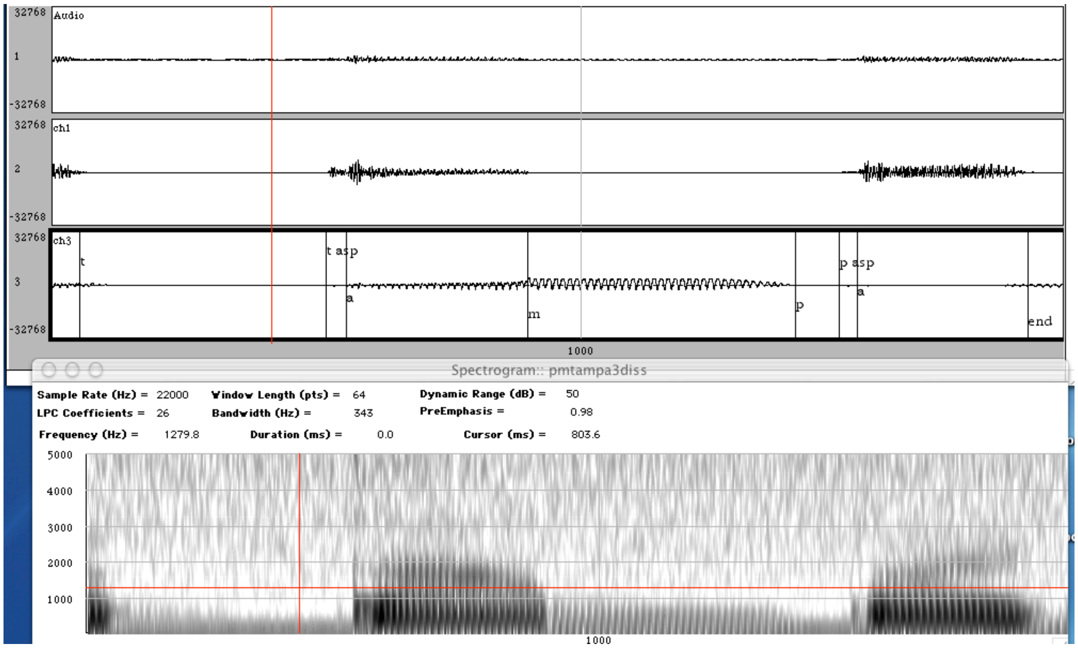
[2] Note that the acoustic data collected simultaneously with the aerodynamic data were used only to aid in segmentation of the latter. All of the acoustic data discussed in this thesis was collected separately with the Marantz, as previously mentioned, for better quality audio data.

Only the token word, not including the frame sentence, is included in the figure for ease of viewing.



Sample Rate (Hz) = 22000
Window Length (pts) = 64
Dynamic Range (dB) = 50
LPC Coefficients = 26
Bandwidth (Hz) = 343
PreEmphasis = 0.98
Frequency (Hz) = 1279.8
Duration (ms) = 0.0
Cursor (ms) = 803.6

Figure 3.7: Labeled airflow data in token of /tampa/ by P6

Analysis and data presentation

Analysis of the airflow data was qualitative rather than quantitative. Each token was viewed individually, and observations of the extent of nasal flow in relevant vowels and consonants was characterized. (For example, "vowel X is nasalized throughout the last third"; "vowel Y has no nasalization".) Nasalization patterns were then compared across repetitions, across forms in the minimal sets, and across speakers. When presenting airflow data in chapter 4, in most cases only the labeled nasal channel will be included.

3.3 Chapter summary

In the first half of this chapter, I discussed the phonetic characteristics of possible relevance to the investigation of NC phonological structure: total duration, nasalization of a preceding vowel, and duration of a preceding vowel. In reviewing past studies and previewing the results of the present study, I argued that consonantal duration is observed to correlate with NC phonological structure, whereas the other two factors are less consistent indicators. Throughout these discussions, I emphasized the importance of carefully controlled, and sufficiently large, phonetic studies when making generalizations about NC phonetics. I then proposed four hypotheses to be investigated, and provided results showing that H4—that vowels are shorter preceding a nasal in a syllable coda than a syllable onset—is not supported by the data in this thesis. The other three hypotheses will be investigated throughout the remainder of the thesis. In the second half of this chapter, I presented methodological details of the phonological and phonetic studies undertaken for this project on Tamambo, Manado Malay, Pamona, and Erromangan.

In chapter 4, I will investigate H3—that vowels are more nasalized preceding a nasal coda than onset—through a presentation of the airflow data. In chapter 5, I will investigate the two hypotheses related to duration, H1—that unary NC segments are similar in duration to comparable unary segments, and H2—that NC clusters are substantially greater in duration than comparable unary segments, through a presentation of the acoustic results.

CHAPTER FOUR:
AIRFLOW RESULTS AND DISCUSSION

4.1 Introduction

In chapter 3, I discussed degree or extent of nasalization in a preceding vowel as a possible cue to the syllable affiliation of a following nasal. Impressionistic studies of several languages note that vowels are more nasalized before a nasal coda than a nasal onset of the following syllable (Herbert 1986), an observation supported by Maddieson and Ladefoged (1993) based on a small qualitative comparison of spectrograms in two Bantu languages. (There have not been any predictions, however, as to the terms or extent of the amount of nasalization difference.) Other phonetic studies have not found support for this claim (Cohn 1990 for Sundanese, English, and French; Adisasmito-Smith 2004 for Indonesian and Javanese). Based upon the former observations—that there is a difference in degree or extent of nasalization in a preceding vowel based upon the syllable affiliation of a nasal—and a wish to test the claim with additional data, the following hypothesis was formulated:

> H3: Vowels are more nasalized preceding a nasal in the syllable coda than preceding a nasal in the onset of the following syllable

The above hypothesis was tested with the languages in the present study. The results of the analyses reveal that vowel nasalization is not related to syllable affiliation of a nasal in these languages. Given that the airflow data are not informative for the larger issue explored in this study—whether or not different phonological NC structures are related to different phonetic characteristics—these data are not presented in full for each of the languages, but rather an overview of the data across the languages, with representative examples, are presented in this chapter.

Two other aspects of the nasal airflow data are addressed in this discussion, despite a lack of prior attention in the literature as to how they might relate to or inform phonological structure. The first factor is the pattern of nasal airflow in NC sequences themselves, and the second is the degree of nasalization in vowels following an NC sequence.

Bilabial and alveolar data from three speakers each of Tamambo, Pamona, and Manado Malay (three repetitions of each token, repetitions two-four) are considered in the discussion, although where questions arose, additional repetitions or speakers were included in the analysis. Data from Erromangan are not considered here, since the most reliable target sets involve nasal-initial words, which means that carryover nasal airflow from a nasal preceding a vowel would likely obscure anticipatory nasal airflow arising from the nasal following the vowel.

In figures where multiple airflow images are compared, the time scales are identical, and tokens are lined up at the beginning of the nasal in each case (and therefore the left edges may be offset.) In cases where it is most relevant, both oral airflow and nasal airflow data are presented, although in the majority of cases only nasal airflow is presented. Voiced NC sequences are labeled as a whole (not with separate nasal-oral portions), allowing the reader to make observations about the relative nasal vs. oral portions based upon the airflow data. As discussed in chapter 3, section 3.2.6, the nasal airflow data are not quantified; rather, the relative amounts are discussed, in relation to a speaker's baseline readings in non-nasal tokens. When discussing amount of nasalization in a given token, I refer to the portion of the segment that contains nasal airflow (for example, a vowel may be 2/3 nasalized before a nasal consonant, meaning the last two-thirds have nasal airflow). I do not make reference to the intensity of airflow (such as whether or not vowels preceding a certain type of nasal are more strongly nasalized during that last 2/3 than when preceding another nasal type). This latter comparison proved less informative, as speakers show little variation in this regard (i.e. a speaker with great intensity of airflow will always show this intensity in nasalized tokens, while a speaker with a lower intensity of airflow will have this lower intensity in all nasalized tokens). Additional information on matters related to methodology can be found in chapter 3, section 3.2.6.

The structure of this chapter is as follows. Section 4.2 offers a summary of preceding vowel nasalization in each of the languages as relates to the above hypothesis, followed by discussion. Section 4.3 contains a description of nasal airflow patterns in the NC sequences themselves. Section 4.4 discusses nasal airflow in vowels following NC sequences, and section 4.5 has the conclusions. The Manado Malay data will be presented first in the discussion of preceding vowel nasalization, since it has both open and closed syllables for comparison.

4.2 Patterns of nasalization in vowels preceding NC

4.2.1 Manado Malay

In Manado Malay, NC sequences are best analyzed as heterosyllabic clusters, as argued in chapter 2, section 2.2.2. Therefore, if the hypothesis that a vowel preceding a nasal coda will be more nasalized than a vowel preceding a nasal onset is in fact true, this difference should be borne out in the Manado Malay data, given that both contexts exist. However, the data do not reveal a relationship between the nasalization patterns on the vowels and the syllabification of the following nasal. Rather, degree or extent of nasalization on a vowel varies across the speakers, tokens, and repetitions.

That vowels are not consistently more nasalized before a nasal in coda position than a nasal in onset position can be illustrated in two ways. First, the degree of vowel nasalization is often the same before a simple nasal and an NC sequence (regardless of whether the sequence has a voiced or voiceless oral portion). The following figure contains nasal airflow data from one repetition each of M4's /tamu/ 'guest', /tamba/ 'to add', and /tampa/ 'place'. In all cases, there is a negligible amount of very low level nasalization throughout the preceding vowel, not much more than that observed in the vowel preceding an oral sound in /taba/ 'patient'. Other speakers exhibit greater amounts of nasality across all of these contexts. Thus, speakers vary, but the variation is not conditioned by the syllabification of the nasal.

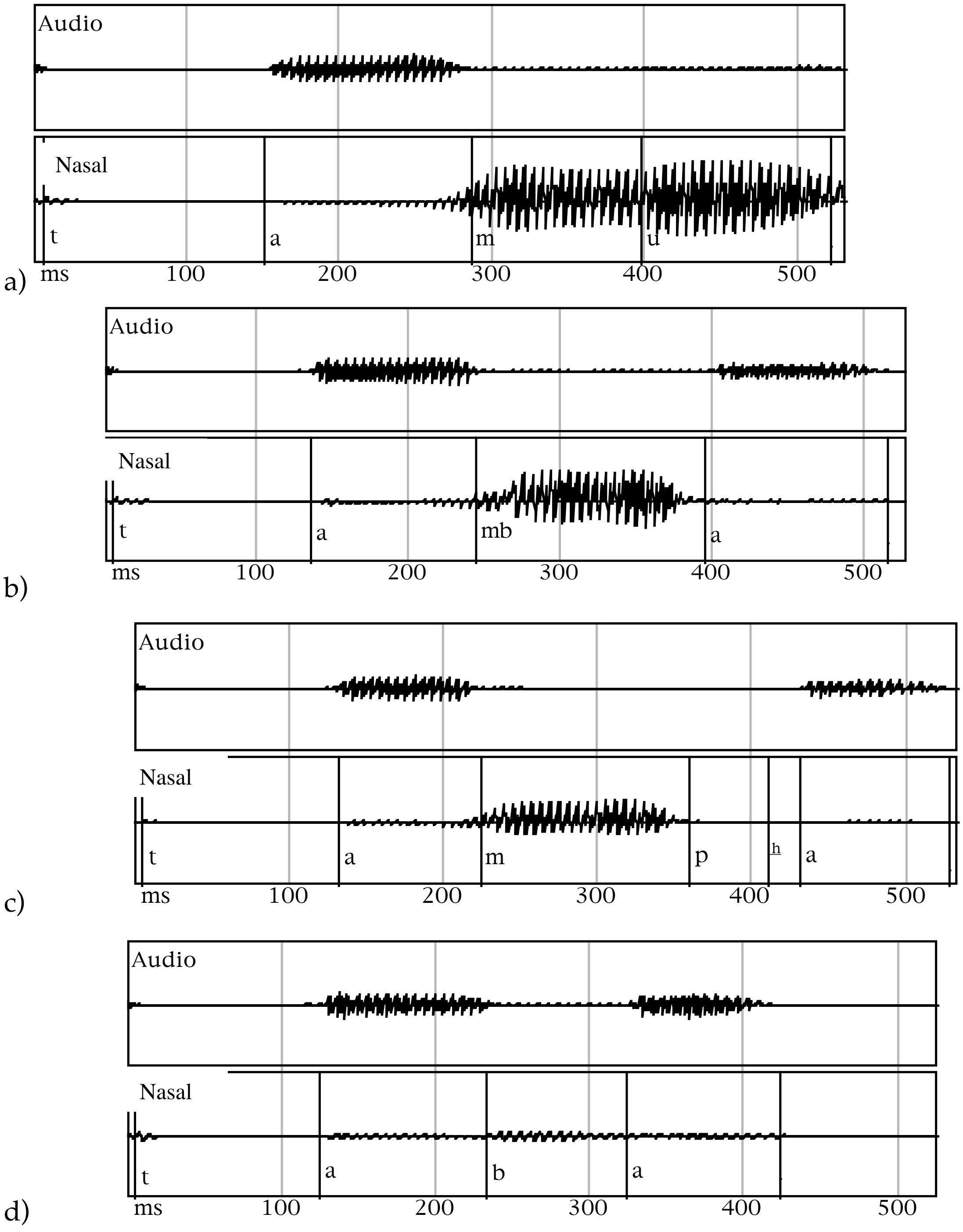


Figure 4.1: Manado Malay. Audio and nasal airflow in /tamu/ (a), /tamba/ (b), /tampa/ (c), and /taba/ (d) by M4.

Second, a speaker may exhibit variability in the degree of nasal airflow in a preceding vowel even across repetitions of the same form. While some variability is expected, if the nasalization were systematically cuing nasal syllabification, we would expect less and more predictable variation. Below are two repetitions of /tana/ ‘earth’ by M6. In the first, there is negligible nasal airflow throughout the preceding vowel, while in the second, there is a moderate degree of nasal airflow throughout the entire vowel.

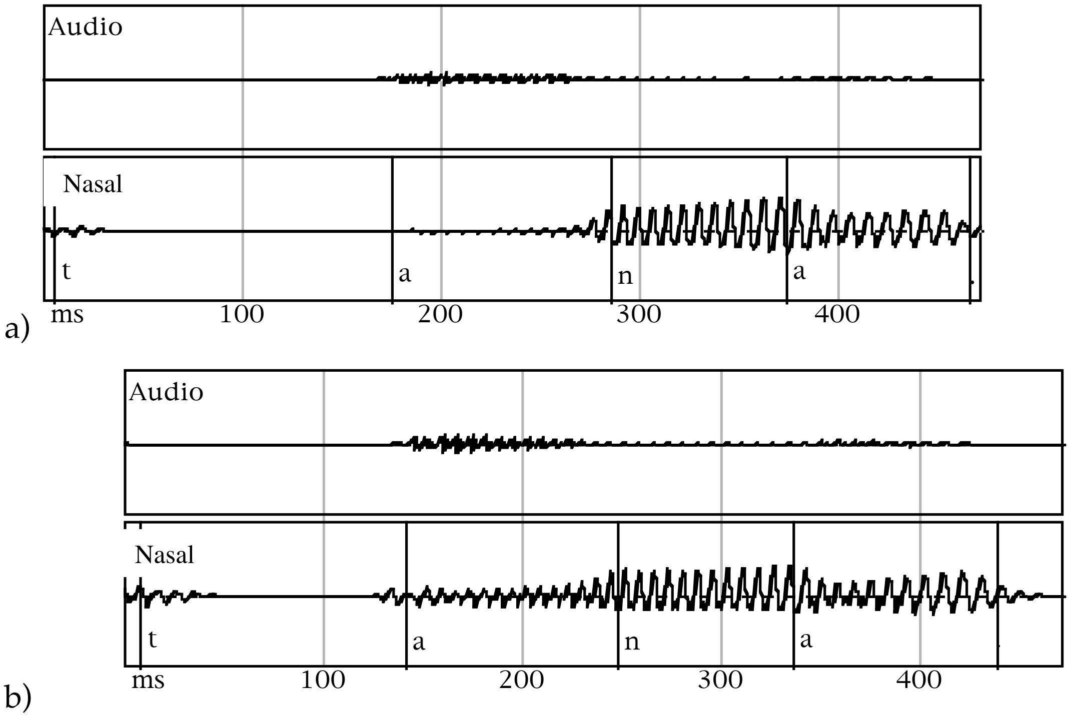


Figure 4.2: Manado Malay. Audio and nasal airflow in two repetitions of /tana/ by M6.

Across the speakers and repetitions in Manado Malay, nasalization in a preceding vowel generally begins no sooner than the last 1/2, and is often not present at all. (The /tana/ token by M6 above in figure 4.2 is somewhat exceptional.) In general, there is variation in vowel nasalization for all of the speakers regardless of the syllable affiliation of the following nasal. The Manado Malay data therefore suggest one of two responses to the hypothesis that vowels closed by a nasal will be more nasalized than vowels followed by a nasal onset. First, the data could indicate that the hypothesis is false, or at least not supported for Manado Malay. Second, the data could suggest that perhaps the hypothesis is true but that the phonological analysis of Manado Malay is incorrect, and that NC sequences in Manado Malay are tautosyllabic. Given the strong arguments in favor of a heterosyllabic analysis for Manado Malay, the latter explanation seems unlikely. The most reasonable conclusion, therefore, is that the hypothesis does not prove true, at least for Manado Malay, and therefore that nasalization of a preceding vowel is not a good diagnostic for syllable affiliation of a following nasal.

4.2.2 Tamambo

In Tamambo, NC sequences are best analyzed as tautosyllabic prenasalized stops, as argued in chapter 2, section 2.2.1. This means that every vowel followed by a nasal is in an open syllable, regardless of whether the nasal is intervocalic or part of an NC sequence. Given the hypothesis that a vowel is more nasalized preceding a nasal coda than a nasal onset, one should not expect a difference in vowel nasalization patterns in Tamambo before N or NC, as only the open context exists. Therefore, one possibility is that vowels in both contexts will have the same amount of nasalization, all else being equal (i.e. place of articulation of the nasal, quality of the vowel), while another possibility is that there will be random variation across tokens (although it is not clear what the latter result would mean for the above hypothesis; see section 4.2.4 for discussion). There also remains the possibility that Tamambo speakers will exhibit a consistent difference in patterns before N and NC (such as more/less nasalization in vowels preceding N/NC). If so, this could mean that the nasalization is a phonetic or phonological effect not conditioned by syllable affiliation of the nasal or that the phonological analysis of Tamambo NCs as tautosyllabic is incorrect.

The data from the three speakers considered here find support for the second possibility—that preceding vowels vary in their amounts of nasalization, unrelated to the identity of the following nasal. One of these speakers (T4), however, does exhibit a tendency for vowels preceding an NC sequence to be more nasalized than vowels preceding a plain nasal, the unexpected third possibility. The former, more general pattern will be illustrated first, followed by consideration of T4's data.

The observation that vowel nasalization appears unrelated to following nasal identity for two of the three Tamambo speakers can be illustrated in two ways. First, a speaker will frequently have the same degree of nasalization before a single nasal as before an NC sequence. For example, the following nasal airflow data from /tano/ 'garden' and /ta^{n}da/ 'to look up' by T1 both show nasalization over approximately the last 2/3 of the vowel.

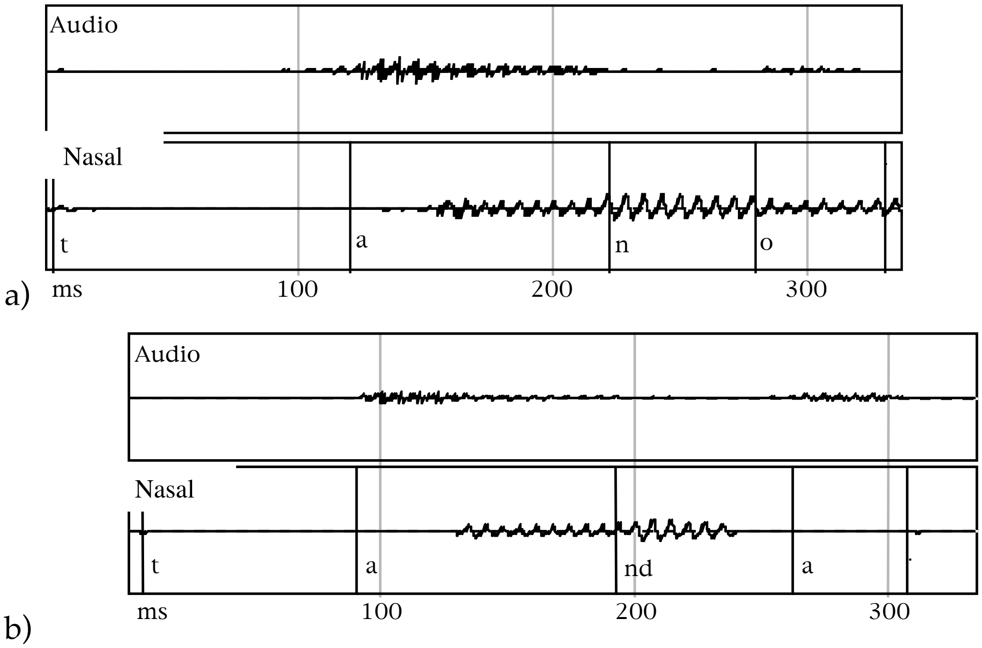


Figure 4.3: Tamambo. Audio and nasal airflow in /tano/ (a) and /ta^{n}da/ (b) by T1.

Second, speakers may show variable amounts of nasalization in a preceding vowel across repetitions of the same form. For example, the following two repetitions of /tama/ ‘father’ by T5 exhibit different degrees of nasalization in the vowel preceding /m/. In repetition 2 (a), nasalization does not begin until approximately the last 1/4 of the vowel, while in repetition 4 (b), nasalization is observed over the final 2/3 of the vowel.

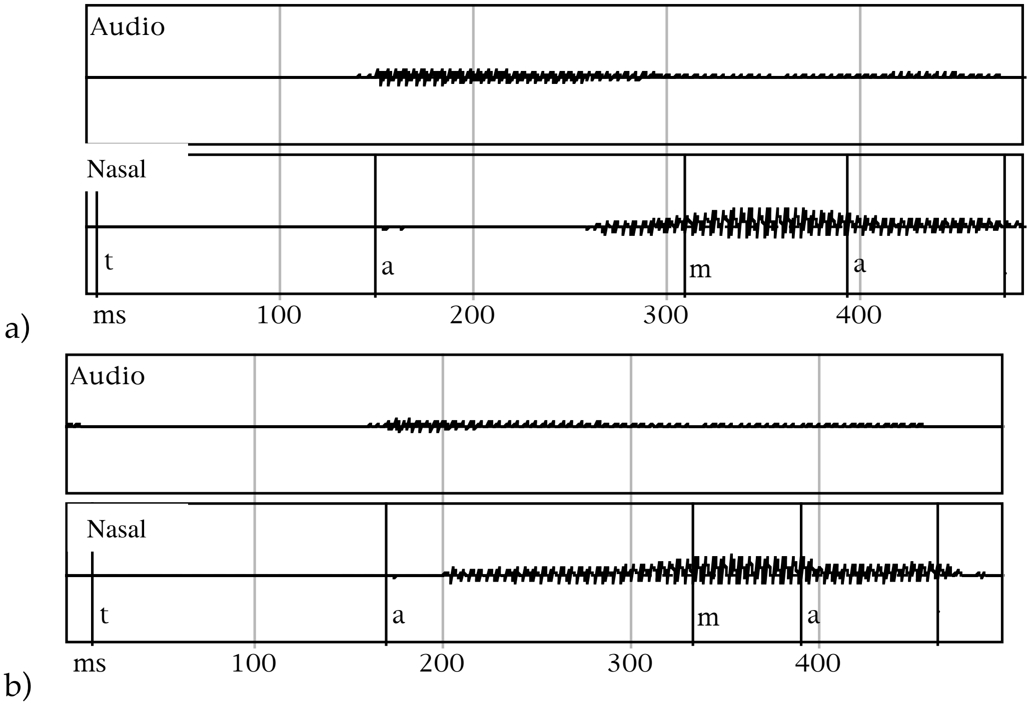


Figure 4.4: Tamambo. Audio and nasal airflow in two repetitions of /tama/ by T5.

For these two Tamambo speakers, the amount of nasalization in preceding vowels varies from about 1/4 to 3/4 of the duration, with T1 having a narrower range (1/2 to 3/4) and T5 having a broader range (1/4 to 3/4). The fact that vowels are not necessarily more nasalized before NC than N is consistent with the expectations of the hypothesis under investigation. How the variation further informs or affects the hypothesis is not clear, and is considered in more detail later.

Although the above descriptive generalizations hold quite strongly for two speakers, they capture the patterns less accurately for a third speaker. T4, although exhibiting some variation across both tokens and repetitions, has a tendency for vowels preceding NC sequences to be more nasalized than vowels preceding plain nasals. In the case of the bilabials, four of the five

/tama/[1] tokens for this speaker have nasalization in about the last 1/2 of vowel, while the other repetition has a very low level of nasalization slowly increasing throughout the duration of the vowel. On the other hand, four of five repetitions of /ta^{m}ba/ have robust nasalization for the entire duration of the vowel, while the other repetition has nasalization in about the last 3/4. Following are representative tokens, with both nasal and oral airflow data, of /tama/ and /ta^{m}ba/ by this speaker.[2]

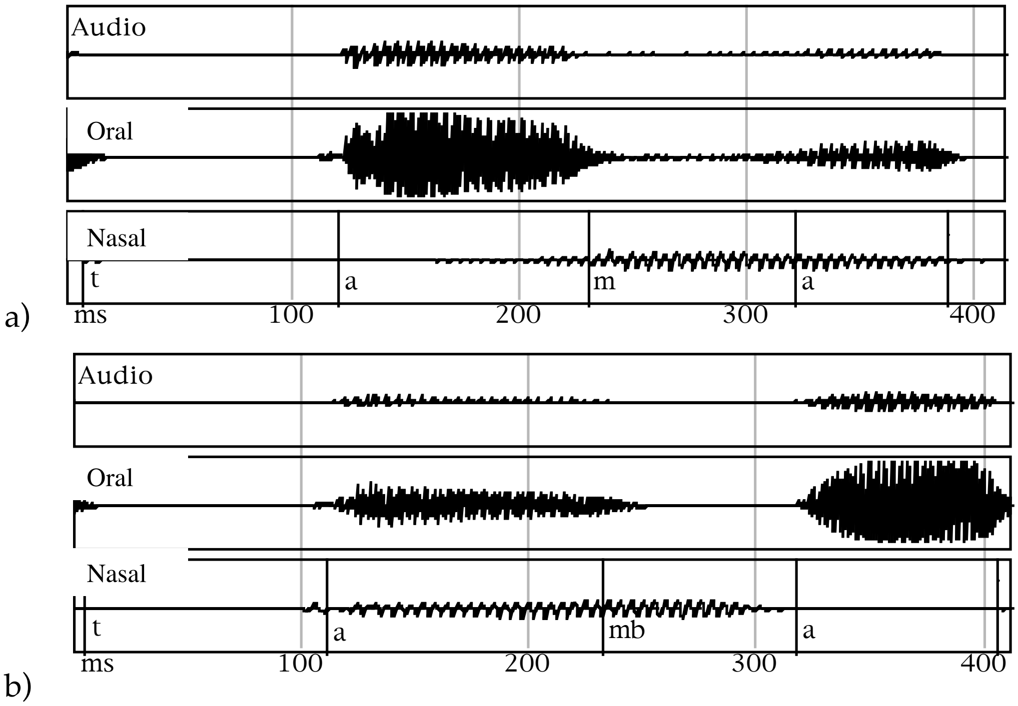


Figure 4.5: Tamambo. Audio, oral airflow and nasal airflow in /tama/ (a) and /ta^{m}ba/ (b) by T4.

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[1] Those primary tokens discussed frequently throughout the thesis will be glossed only at their first occurrence in each chapter.

[2] Patterns of oral airflow are also different in these forms, with greater oral airflow paired with less nasal airflow in the /tama/ cases, and less oral airflow paired with increased nasal airflow in the /ta^{m}ba/ cases. I do not yet have an explanation for this, although it may be related to vowel quality.

The difference in nasalization before N and NC for this speaker is less pronounced for the alveolars, but still consistently different. All repetitions of /tano/ have either no nasalization during the /a/, or very low level and slowly increasing nasalization, while all /ta^{n}da/ repetitions have relatively robust nasal airflow throughout the entire preceding /a/, as seen below.

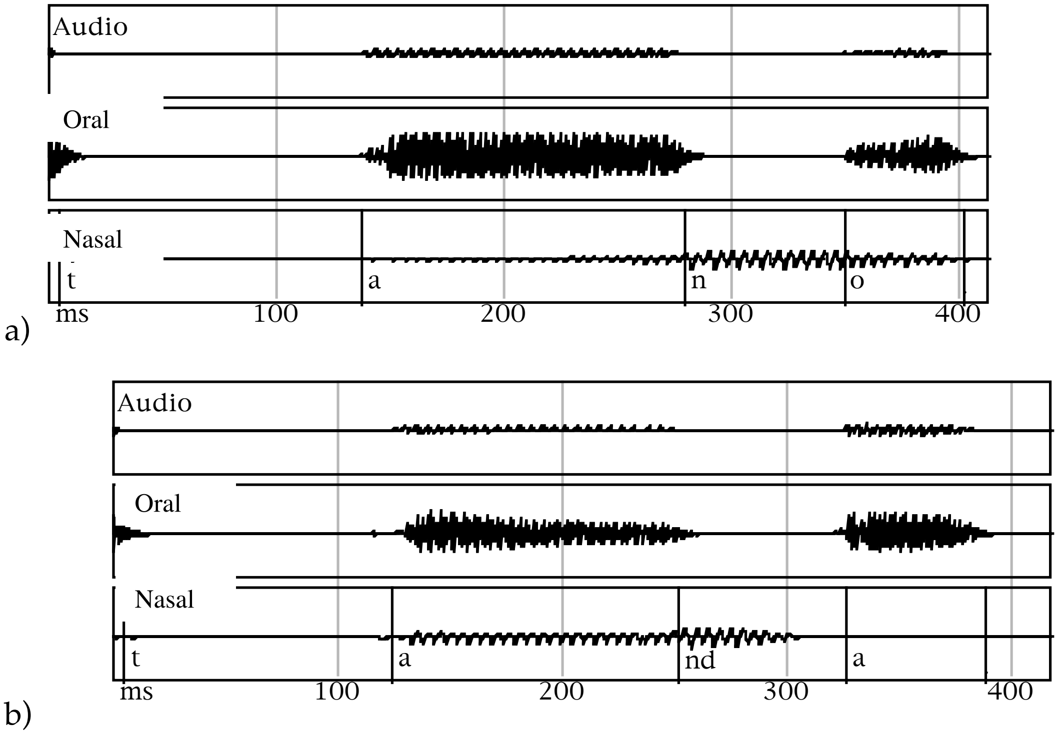

Figure 4.6: Tamambo. Audio, oral airflow and nasal airflow in /tano/ (a) and /ta^{n}da/ (b) by T4.

Looking at the above data, one might conclude that the vowel nasalization diagnostic for nasal affiliation is in fact useful and is providing evidence that NC sequences in Tamambo are heterosyllabic clusters with the nasal in coda position. However, this conclusion can be rejected on two counts. First, the phonological evidence that NC sequences in Tamambo are unary is quite strong, as outlined in chapter 2, section 2.2.1: this is not a case of ambiguous phonological status. Second, the nasalization patterns of the other two speakers are not predictable based upon identity of a following nasal. The data from T4 are therefore quite intriguing. This speaker does have a different pattern of vowel nasalization before prenasalized stops and simple nasals, a difference related to segment identity but *not* related to syllable affiliation of the nasal. This case will be discussed in more detail in section 4.2.4.

4.2.3 Pamona

In Pamona, NC sequences are best analyzed as tautosyllabic, as argued in chapter 2, section 2.2.3. The claim in that chapter is that the sequences form clusters rather than unary segments. However, since the hypothesis under investigation—that vowel nasalization is greater before a nasal coda than a nasal onset—is related to syllable structure rather than segmenthood—the segmental status of the sequences in Pamona should not necessarily affect an examination of this issue. Given that the sequences are tautosyllabic and that all vowels preceding any type of nasal are therefore in open syllables, the prediction about Pamona is that vowels should not be more nasalized before NC sequences than plain nasals. Although data from the previous two languages suggest that the hypothesis about vowel nasalization presented at the outset is not true, it is still worthwhile to examine the claim in yet another language, or to see if Pamona differs from Tamambo and Manado Malay in some other ways that might relate to phonological structure or prove informative.

The Pamona data reveal that the nasalization in vowels preceding plain nasals does not differ from nasalization in vowels preceding NC sequences. There is, however, great variation in the data unrelated to identity of the following nasal, as was also seen in Tamambo and Manado Malay. Similar to these languages, the fact that vowel nasalization and syllable affiliation of a following nasal are not related can be illustrated in two ways. First, speakers may have the same amount of vowel nasalization before N as before NC. For example, the following figure contains nasal airflow in a repetition of P3's /tono/ 'to knock head' and a repetition of /tondo/ 'next to', each with a preceding vowel that has nasalization covering approximately the last 3/4.

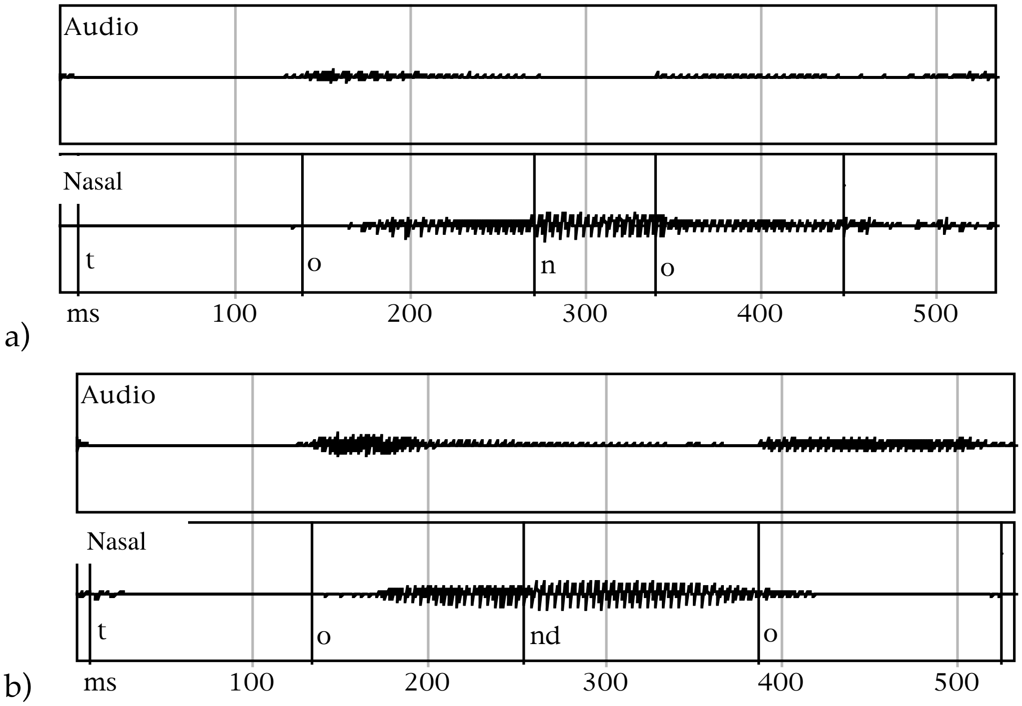

Figure 4.7: Pamona. Audio and nasal airflow in /tono/ (a) and /tondo/ (b) by P3.

The above example illustrates similarity in vowel nasalization before a plain nasal and a voiced NC sequence. The following figure illustrates the same phenomenon before a plain nasal and NC̥ sequence. These examples by the same speaker are of /tama/ 'uncle' and /tampa/ 'place', where a low level of nasalization extends throughout the entire duration of the preceding /a/.

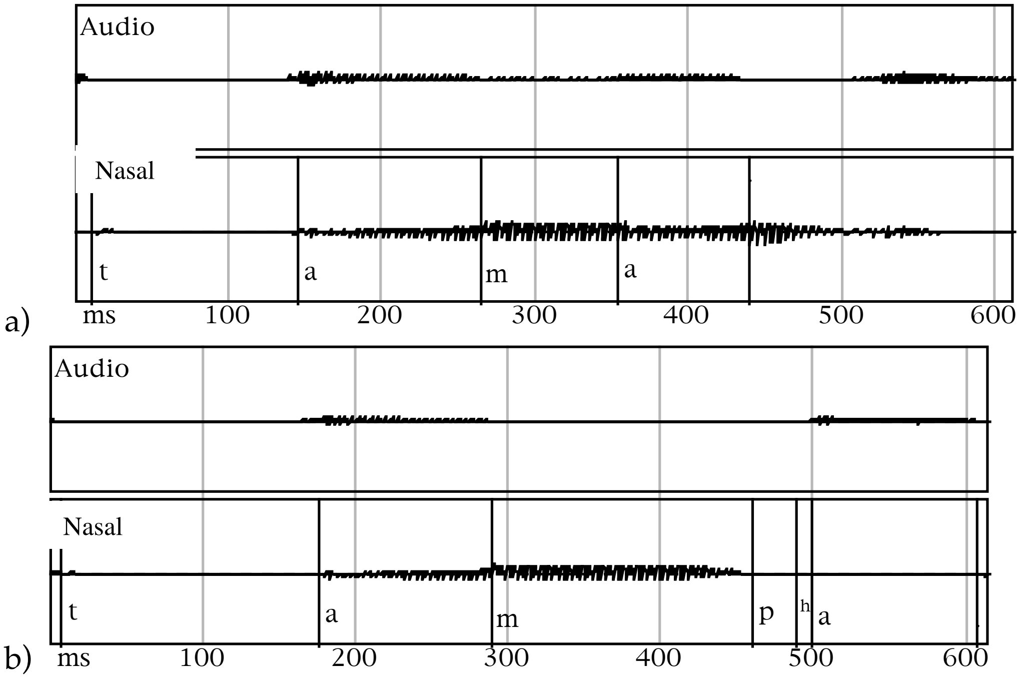

Figure 4.8: Pamona. Audio and nasal airflow in /tama/ (a) and /tampa/ (b) by P3.

Second, the amount of vowel nasalization before a particular nasal segment can vary across a speaker's repetitions of the same token. The following figure contains two repetitions of P2's /tombu/ 'to draw water', the first exhibiting nasalization for 9/10 of the duration of the vowel, and the second exhibiting nasalization for only the final 1/2 of the vowel. (Note that the low level nasalization observed in the first half of the vowel in /tombu/ is typical of this speaker's vowels, even those preceding non-nasal consonants.)

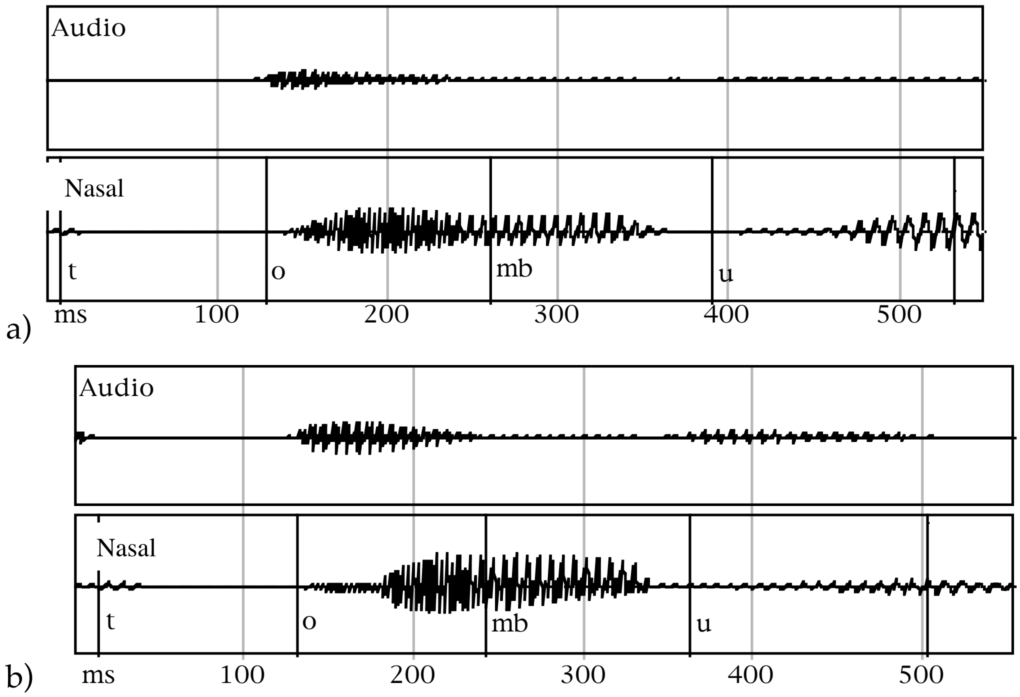

Figure 4.9: Pamona. Audio and nasal airflow in two repetitions of /tombu/ by P2.

Across the speakers and repetitions, the amount of nasalization in a vowel preceding a nasal consonant varies from no nasalization to complete nasalization, with clear speaker differences. For speakers P2 and P3, preceding vowels tend to be nasalized for at least the final 1/2 of the duration, up to the entire vowel duration, while for P6, preceding vowels are always less than 1/2 nasalized, and sometimes have no nasal airflow at all. The fact that Pamona speakers do not have a tendency to nasalize vowels more before NC sequences than plain nasals does not contradict the hypothesis that nasalization relates to syllabification of the nasal, since all syllables are open in Pamona. What the observed variation might mean for this hypothesis is considered below.

4.2.4 Conclusion- Vowel nasalization

The hypothesis explored in this section is that vowels will be more nasalized preceding a nasal in coda position than a nasal in onset position. The interest in this issue is in using vowel nasalization as a diagnostic for determining syllable affiliation of the nasal, and therefore to aid in analyzing the phonological structure of an NC sequence. The data presented in this chapter suggest that, for these languages, vowel nasalization does not vary based upon the structure of the following nasal, and therefore such nasalization may not be useful as a diagnostic in determining syllable affiliation.

This hypothesis fails on two accounts. First, in the one language in the data with a contrast between vowels preceding nasal codas versus nasal onsets—Manado Malay—there is no difference in patterns of vowel nasalization in the two different contexts, and thus no indication that vowel nasalization is related to nasal syllabification. Second, in all of the languages, there is a great deal of variation observed in the amount of nasalization preceding the plain nasals and NC sequences across the repetitions and speakers, much more variation than would be expected if nasalization were consistently cuing nasal syllable affiliation.

It might be possible to argue that in some languages, both nasalization based upon syllable affiliation of the nasal as well as phonetic nasalization over a wide window are at work, with the phonetic sometimes obscuring the phonological. However, there does not seem to be an indication of this in the Manado Malay data (the only language in the data with both open and closed syllables). Additionally, it might be possible to claim that for languages with only open syllables, such as Pamona and Tamambo, the hypothesis does not make any predications and that a full range of variation in phonetic vowel nasalization is therefore possible. However, given that there is as much variation in Manado Malay as there is in Tamambo and Pamona, such an explanation is not illuminating.

Further, the one speaker in the data who appears to exhibit a difference in vowel nasalization preceding a simple nasal versus an NC sequence is a speaker of Tamambo. Of the languages considered, Tamambo is the most clear-cut case of a language with unary NC sequences, which means that vowels preceding both N and NC are in open syllables. Therefore, Tamambo should be the *least* likely to exhibit a difference in vowel nasalization patterns. The data from this speaker are considered further at the end of this section.

The primary conclusion reached in this section—that syllable affiliation of the nasal does not have an affect on nasalization patterns of the preceding vowel—is corroborated by data from two other studies. As discussed in chapter 3, section 3.1.3, Cohn (1990) considered this issue in her nasal airflow studies of Sundanese, French, and English, and concluded that nasal airflow was not greater before a nasal coda than a nasal onset, and Adisasmito-Smith (2004) came to the same conclusion for Indonesian and Javanese based upon acoustic measures of nasalization. It appears, therefore, based upon data from these eight languages (the three in this section and the five in those studies), that the hypothesis that a vowel will be more nasalized before a nasal coda does not prove true. The only instrumental study to suggest otherwise is Maddieson and Ladefoged's (1993) comparison of Luganda and Sukuma. It may be that their hypothesis is indeed correct for these Bantu languages (or relates in some way to moraic structure of the nasal, an issue less relevant for the languages in this study); however, given that their study is not quantitative and makes use of data from only one speaker of each language (which is potentially problematic, considering the single speaker in this study who exhibits different patterns), the results should be viewed as inconclusive pending a larger study with a reliable quantitative measure of nasalization.

Despite their different phonological structures, patterns of vowel nasalization in Tamambo, Manado Malay, and Pamona look very similar. The variation and variability in nasalization patterns unrelated to syllable structure suggests that the nasalization is phonetic. Given the lack of phonologically nasal vowels in each of the languages and a lack of evidence for phonological processes of vowel nasalization, a reasonable argument can be made that all of the vowels are unspecified for nasality. As argued by Cohn (1993a), vowels that leave the phonology unspecified for [nasal] may show gradient nasal airflow patterns, for example, a cline-like increase in nasal airflow between a segment specified as oral and one specified as nasal (while those specified for [nasal] will have plateaus in nasal airflow—nasal airflow for the full duration of a [+nasal] segment, no nasal airflow for the full duration of a [-nasal] segment). In the case of the present data, it appears that during the articulation of a vowel preceding a nasal, speakers can lower the velum in preparation for the following nasal at any point during the duration of the vowel without affecting the identity of the vowel, and therefore some variability is not surprising. However, even though some variability is expected, it remains unclear why such a great amount of variability is observed. Why, for example, do speakers not have the same cline-like pattern in all cases? A systematic study of this topic in a wider range of languages, with different phonological patterns of vowel nasalization, would help inform the issue.

Finally, although the nasalization patterns appear equally variable for each of the three languages (speaker T4 excluded), there are some slight differences in overall degrees of nasalization in the languages. Generally, Tamambo speakers have the most nasalization across all segment-types while Manado Malay speakers have the least, with Pamona falling somewhere in between. These observations suggest that there may be language-specific phonetics at work, affecting how much overall nasal airflow is present in a given language.

Nasal airflow pattern for T4

If the pattern exhibited by T4, whereby vowels are more nasalized before prenasalized stops than plain nasals, is not related to differences in syllable affiliation of the nasal yet is nonetheless consistent, then the differences must be related in some way to the identity of the nasal segments. What might be the cause of this?

A point worth considering in this regard is Sefton and Beddor's (2005) observation that a constant-sized nasal gesture may be maintained across syllables. In studies of English, they find an inverse relationship between nasal consonant duration and duration of coarticulatory vowel nasalization. In a CVN context, relatively short nasals in codas follow vowels with relatively long periods of anticipatory nasalization, while in a NVC context, relatively long nasals in onset position precede relatively short periods of carryover nasalization in a following vowel, suggesting a velic gesture of relatively stable duration. Similarly, Sefton and Beddor find that vowels before relatively short nasals in a VNC̥ context have longer periods of nasalization than those before relatively long nasals in a VNC̬ context. They cite other cases of this inverse relationship between the duration of a nasal consonant and nasalization on an adjacent vowel, in Italian (Busà 2003) and Thai (Onsuwan 2005). Such trade-offs may have implications for sound change, for example leading to phonologization of the vowel nasalization in the VNC̥ case and loss of the nasal consonant.

As will be seen in chapter 5, section 5.2, for some speakers of Tamambo, the nasal portion of a prenasalized stop is shorter in duration than a plain nasal. If the nasal gesture associated with a nasal consonant is of relatively stable duration, then perhaps the gesture begins earlier in a vowel preceding a prenasalized stop than a plain nasal. Given that T4 consistently has shorter nasal closures in prenasalized stops than plain nasals, more so than most of the other speakers in the data, this speaker would be the most likely to exhibit the observed vowel nasalization difference. Exploring such an explanation for T4's data is purely speculative at this point and in need of further investigation. Note, as a possible criticism of this account, that the difference in extent of vowel nasalization before prenasalized stops and plain nasals for T4 is much greater than the difference in duration between the nasal closures of the corresponding consonants. There is also the issue of how the duration of the nasal gesture relates to progressive vowel nasalization, as discussed in section 4.4.

4.3 Patterns of nasal airflow in NC

There has been little attention in the literature as to how relative patterns of nasal-oral timing within an NC sequence may relate to phonological structure. Nevertheless, it is interesting to consider the nature of nasal airflow in these sequences, to determine if there may in fact be a relevant relationship between the phonology and phonetics, and simply to learn more about the characteristics of nasal airflow, given the relatively small amount of such data in the literature. Ultimately, the data in this study reveal that nasal airflow patterns within an NC sequence do not vary in accordance with phonological structure. Furthermore, there is not the phonetic variability observed in the case of vowel nasalization, rather, the nasal airflow patterns in the NC sequences are quite invariant across sequence-types and across speakers in all three of the languages. Given the similarity in results for all of the languages, phonological structure will not be the focus of this section. Rather, the data from all of the speakers will be considered as a whole, with the goal of contributing to our understanding of nasal airflow patterns in NC sequences. The nature of voiced NC sequences will be discussed first in section 4.3.1, followed by a discussion of the NC̥ sequences in section 4.3.2.

4.3.1 Voiced NC sequences

There is one primary, and almost exceptionless, observation that can be made about voiced NC sequences across the languages and speakers. Virtually the entire closure of a voiced NC sequence consists of nasal airflow (i.e. there is crucially not necessarily a distinct nasal portion followed by a distinct oral portion, as one might expect from comparisons with other consonant sequence-types). In the vast majority of cases, the nasal portion of the sequence comprises at least 9/10 of the total closure and often the entire closure. (Although there are occasional tokens where nasal airflow comprises as little as 3/4 of the closure, these cases are exceptional, and no speaker has this relatively small amount as a tendency). Following are nasal airflow tokens from each language illustrating nasal airflow throughout an alveolar NC̬ closure: a prenasalized stop in /ta^{n}da/ by T5, a heterosyllabic cluster in /tanda/ by M3, and a tautosyllabic cluster in /tondo/ by P6:

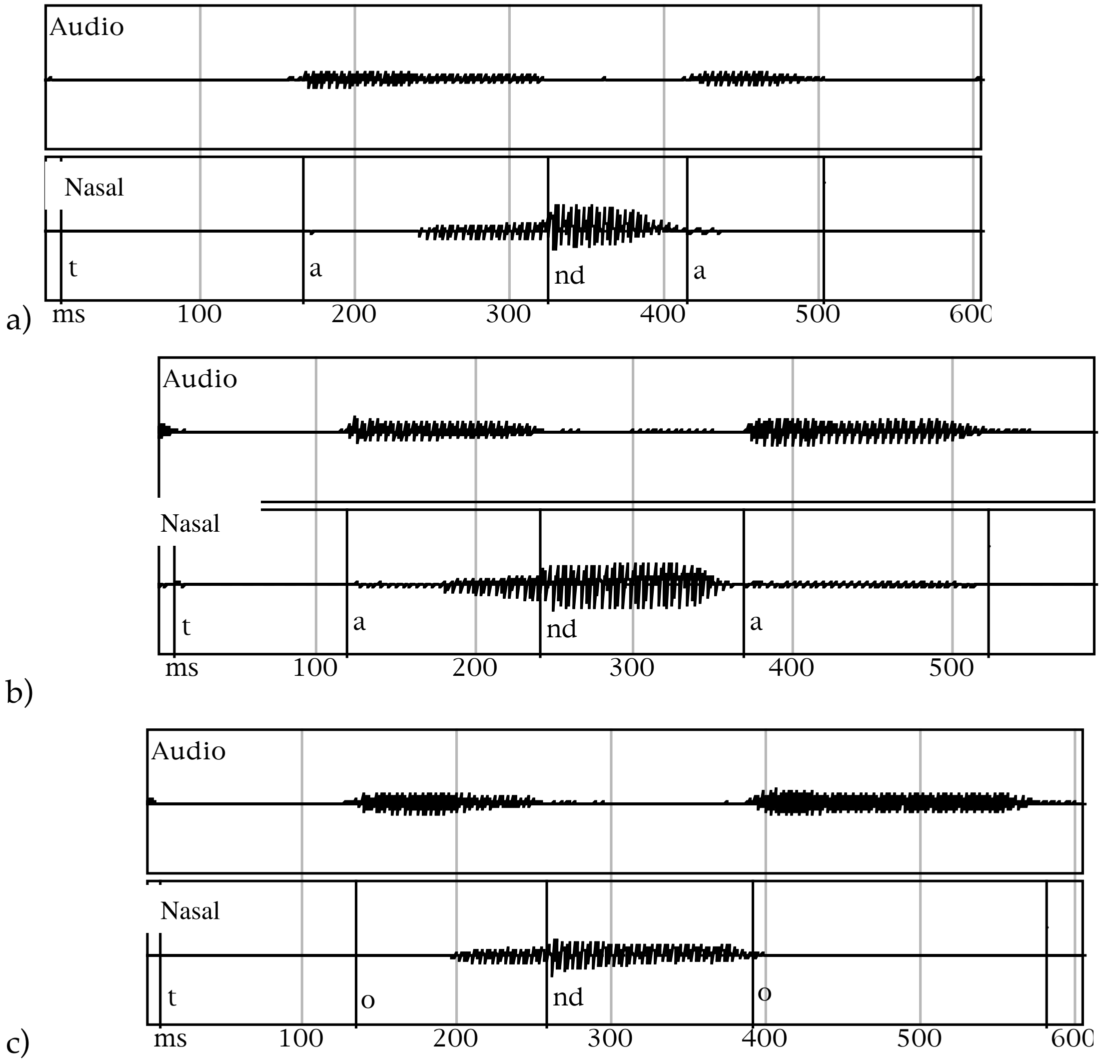

Figure 4.10: Audio and nasal airflow in /ta^{n}da/ by T5 (a), /tanda/ by M3 (b), and /tondo/ by P6 (c).

As seen above, all voiced NC sequences have the aforementioned pattern regardless of the phonological structure of the sequence, being primarily nasal whether the sequence forms a prenasalized stop or a cluster. (As will be seen in chapters 5 and 6, this fact, combined with the differences in total duration between unary and clusters NC sequences, yields interesting consequences for the phonology.)

Nasal airflow extending throughout the duration of a voiced NC sequence has been observed in other languages as well, including the prenasalized stops in Fijian (Maddieson 1988); the NC clusters in Sundanese, French, and English (Cohn 1990); and the prenasalized stops in Ikalanga (Beddor and Onsuwan 2003). There are no cases, to my knowledge, where a more substantial oral closure has been reported. It is therefore possible that this pattern of nasal airflow is indicative of a universal phonetic pattern for voiced NC sequences, regardless of phonological structure. Although a systematic study of this topic is still needed, it is possible to speculate about several possible related causes of this pattern. If the presence of a more substantial oral portion in NC sequences is not crucial for perception (a topic discussed in section 4.4 below), then a transition to oral airflow earlier in the closure is unnecessary. Given that maintenance of vocal fold vibration is aided by allowing air to escape through the nose, as mentioned in chapter 1, section 1.4), continuing nasal airflow throughout the closure would be easier than articulating a voiced closure without the nasal airflow. Further, if there is no cause for ceasing nasal airflow at a particular point during the closure, the velum and oral articulators do not have to be precisely coordinated in time, and the transition can happen gradually, as long as it does so before the onset of the vowel. The issue of the phonetic motivations for the nasal airflow pattern found in NC sequences, as well as whether or not these phonetic characteristics could offer insight more generally into the structure of NC sequences, is in need of further investigation.

The above generalization—that voiced NC sequences are composed of nasal airflow for most of their total duration—holds strongly across the languages. There is some variation, however, in the acoustic characteristics of the final portion of the sequence (from the cessation of nasalization to the onset of the vowel). This variation exists across languages and across repetitions for a given speaker, although individual speakers do tend to have their own consistent patterns. First, some speakers have a completely nasal NC sequence with no clear oral portion, ending with an abrupt cessation in nasalization at the onset of the vowel. P3 is such a speaker, as illustrated by the nasal flow in a token of /tondo/, below:

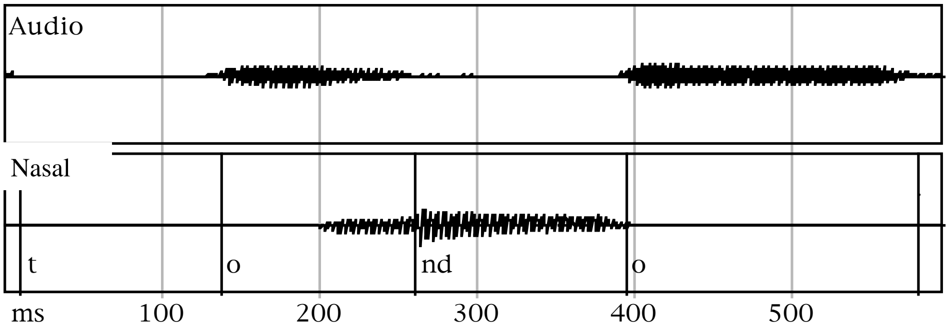

Figure 4.11: Pamona. Audio and nasal airflow in /tondo/ by P3.

Second, some speakers have a clear oral closure before the vowel onset. T1 is such a speaker, as illustrated by the nasal airflow in a token of /ta^{n}da/ below:

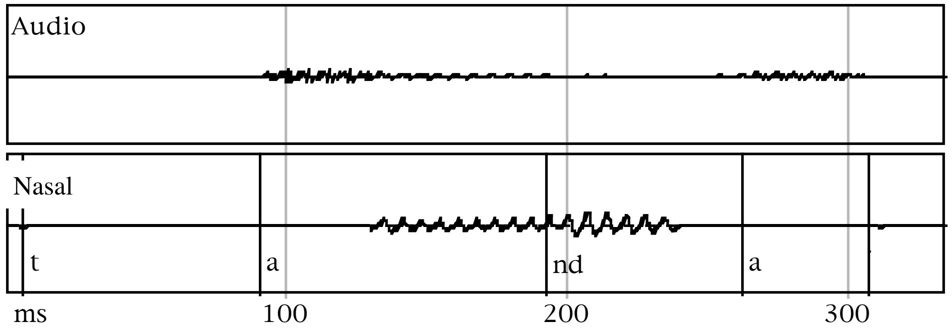

Figure 4.12: Tamambo. Audio and nasal airflow in /ta^{n}da/ by T1.

Finally, two speakers (M4 and M6) have a majority of tokens where nasalization from the NC sequence extends slightly into the following vowel and then quickly tapers off for the remainder of the vowel. These data appear somewhat unusual, both compared to other data in this study and those in past studies. The following example shows this lag of nasalization in /tanda/ by M4:

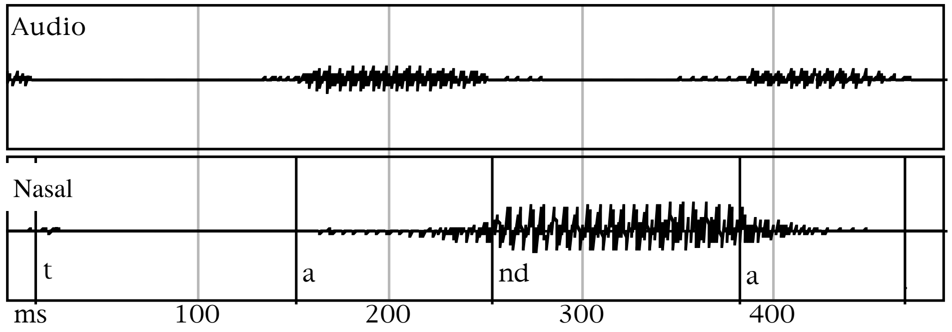

Figure 4.13: Manado Malay. Audio and nasal airflow in /tanda/ by M4.

The amount of nasalization in the beginning of the following vowel is relatively small, however, when compared to the complete nasalization of vowels following plain nasals for all of the speakers, as can be seen in section 4.4.

Although a speaker may tend towards a particularly pattern, there are certainly exceptions. In general, Tamambo speakers are the most likely to have an oral closure and Manado Malay speakers are the least likely, with Pamona speakers falling somewhere in between, but these are broad generalizations.

4.3.2 NC̥ sequences

The nasalization pattern of NC̥ sequences differs from that of voiced NC sequences. In the NC̥ cases, there is a clear oral closure during the second portion of the NC sequence and frequently an aspirated release. The amount of nasalization differs slightly between Manado Malay and Pamona. (Tamambo does not have NC̥ sequences). In Manado Malay, the nasal portion of the sequence usually comprises just slightly more than the first 1/2 of the sequence. In Pamona, the extent of the nasal airflow is greater, generally comprising 2/3 to 3/4 of the entire sequence. In all cases, the transition from nasal to oral is fairly abrupt. Following is a representative example of an /nt/ sequence in each of these languages, from the word /tanta/ in Manado, and from the word /wuntu/ ‘amputated’ in Pamona.

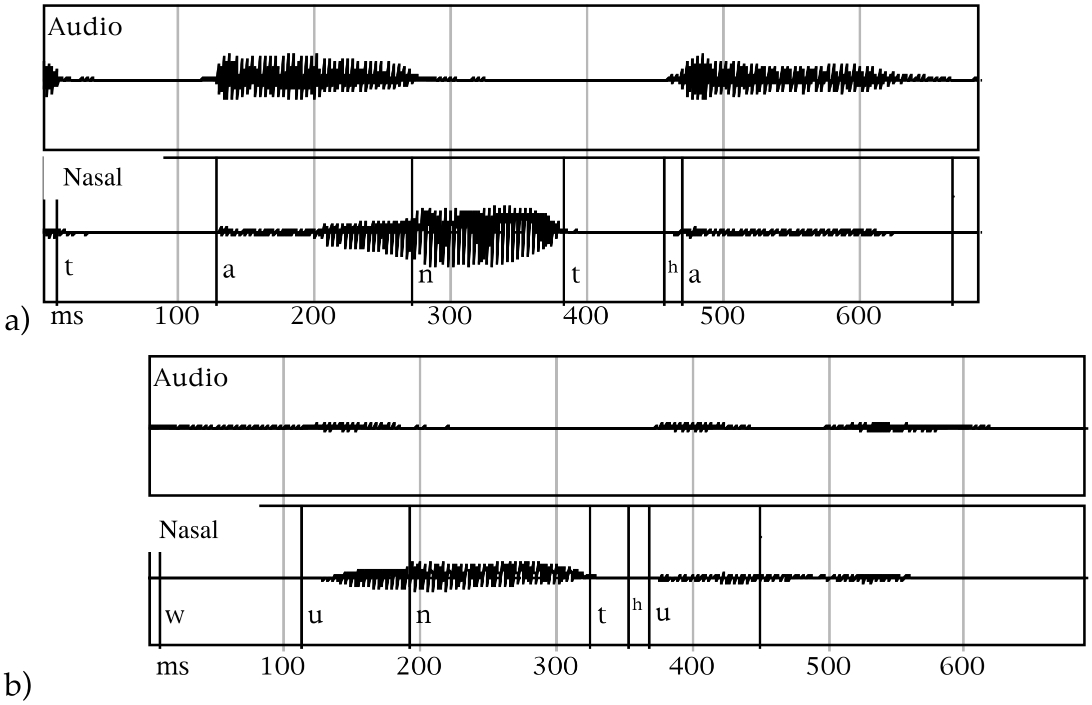

Figure 4.14: Audio and nasal airflow in /tanta/ by M3 (a) and /wuntu/ by P3 (b).

The tendencies described above hold across the speakers of each language at both the bilabial and alveolar places of articulation. It is not clear whether these differences in the extent of nasal airflow in the NC closure (or, looked at in another way, the relative durations of /n/ and /t/ in a cluster) relate in any way to phonological structure. At the least, they likely illustrate some language-specific phonetic implementation for NC̥ sequences in these languages.

The NC̥ sequences in this study differ greatly from NC̬ sequences in that the former have substantial oral closures while the latter have negligible oral closures (in addition to a difference in vocal fold vibration). This is also consistent with observations in the previous literature. If, as mentioned in chapter 1, section 1.4 and discussed in more detail in section 4.4 below, the oral closure is relatively insignificant for the percept of an NC̬ sequence, it is likely quite important for the percept of an NC̥ sequence. A study of NC̥ sequences that examines the relative importance of various perceptual factors would be informative.

4.4 Extent of nasalization in a following vowel

Another notable characteristic of NC sequences is that a vowel following an NC sequence is oral rather than nasal. This is not surprising given that an oral vowel is expected in this context due to the oral specification on the right edge of the sequence (e.g. Anderson 1976). By contrast, however, in all three of these languages, a vowel following a simple nasal is strongly nasalized for its entire duration, thereby exhibiting a robust rule of progressive nasalization. This differs from vowels preceding any sort of nasal in these languages, where some degree of anticipatory nasalization is often seen, but rarely for the full duration of the segment, and usually without as much intensity.

Given that an NC sequence can be entirely nasal and potentially largely undistinguished from a plain nasal (especially in cases where duration does not offer a cue to identity, as will be seen in Tamambo, for example), the nasal/oral quality of the following vowel is likely an important cue for identification of the consonant. In a language with prenasalized stops, for example, an oral vowel following a nasal segment indicates that the preceding segment is a prenasalized stop while a nasalized vowel following a nasal segment indicates that the preceding nasal segment is a plain nasal. In a study of the perception of prenasalized stops versus plain nasals in Ikalanga, Beddor and Onsuwan (2003) find that carryover nasalization—its absence following prenasalized stops and its presence following plain nasals—is the primary perceptual cue, both “necessary and sufficient”, to segment identity. This cue proves even more important than the presence of an oral burst in prenasalized stops.

It has been observed that Austronesian languages tend to have rules of progressive, rather than anticipatory, nasalization, as noted by Robins (1957) and discussed by Cohn (1993a) for Sundanese, and observed by Cohn (1993b) and Blust (1997) in a wider range of languages in the family, an observation clearly supported by the data from these three languages. The following example from Tamambo contrasts a final nasalized vowel following a simple nasal in /tama/ with a final oral vowel following an NC sequence in /ta^{m}ba/. This example from T1 is representative for all of the languages in the study.

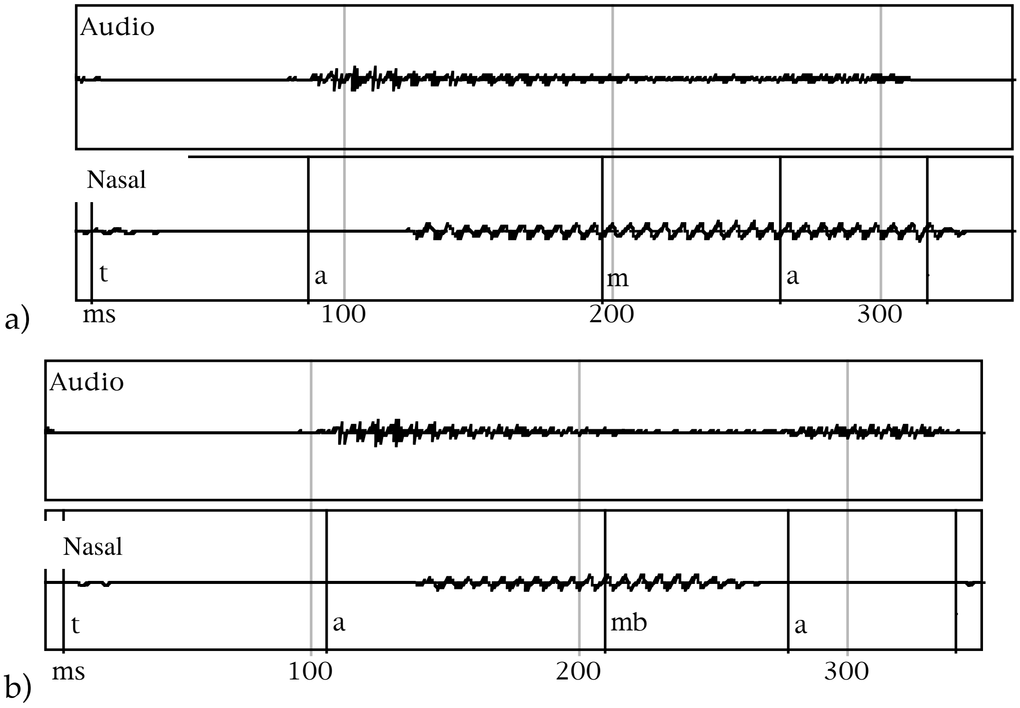

Figure 4.15: Tamambo. Audio and nasal airflow in /tama/ (a) and /ta^{m}ba/ (b) by T1.

For some speakers, nasal airflow continues even after oral airflow for the vowel has ceased, resulting in increased nasal airflow towards the end of the vowel. The following example from P2 illustrates this increase in nasal airflow at the end of /tama/:

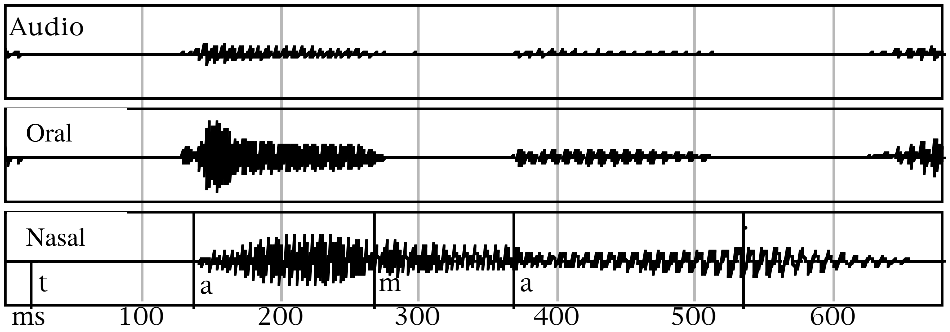

Figure 4.16: Pamona. Audio, oral airflow and nasal airflow in /tama/ by P2.

Furthermore, there is an indication that the progressive nasalization may be long-distance, affecting segments beyond the immediately following vowel (again consistent with observations about other languages in the family). This can be seen in Pamona, where nasal airflow initiated for the /ŋ/ in /ŋojo/ ‘gorge’ extends throughout the word, nasalizing the immediately following /o/ as well as the glide /j/ and final /o/. The nasalization ends at the onset of the oral affricate /dʒ/ in the following word /dʒa/ ‘now’ from the frame sentence. The following figure illustrates this long distance progressive nasalization in /ŋojo/ (a), as compared to a word where all segments lack nasalization— /gola/ (b). Note that while many speakers have a very small amount of nasal airflow apparent even in oral vowels and voiced oral stops, P6 never exhibits any noticeable nasal airflow in her oral tokens, as seen in /gola/, resulting in a striking contrast between the nasal and oral tokens.

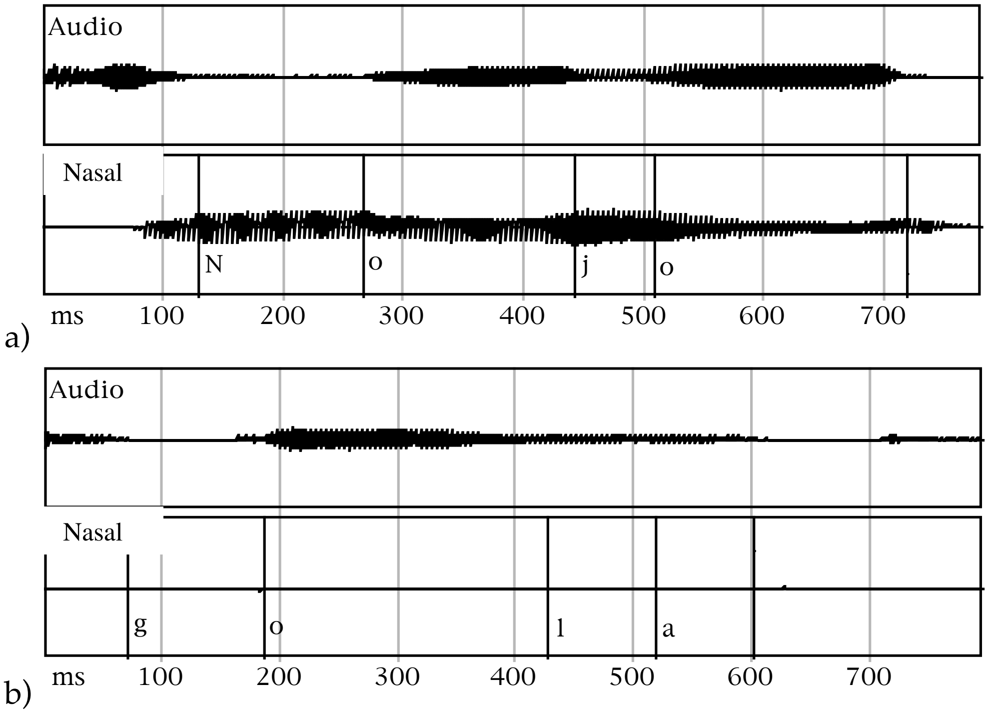

Figure 4.17: Pamona. Audio and nasal airflow in /ŋojo/ (a) and /ɡola/ (b) by P6. [Note: “N” represents /ŋ/.]

Aside from the word /ŋojo/ in Pamona, there are no forms in the present data that offer a context for further exploring this issue (as this topic is peripheral to the focus of this study). A preliminary investigation of other forms in Pamona, including /ŋale/ ‘chasm’ and /ŋaru/ ‘cat’, suggest that the nasalization cannot extend to liquids (again consistent with related languages), although this issue is in need of further investigation.

4.5 Conclusion

The hypothesis under investigation in this chapter was that a vowel is more nasalized preceding a nasal in coda position than a nasal in onset position. The data from Manado Malay—the language with nasals in both coda and onset position—indicate that the hypothesis does not hold true, at least for this language. Rather than have different patterns of vowel nasalization before nasal codas and onsets, speakers exhibit wide variation in nasalization patterns across the forms and across repetitions of the same form, as do the speakers of the tautosyllabic NC languages Tamambo and Pamona. Two other nasal airflow factors were discussed as well. It was found that nasal airflow extends throughout almost the entire duration of voiced NC sequences in all three of the languages, while NC̥ sequences have distinct nasal portions followed by distinct oral portions. It was also found that all three languages exhibit heavy progressive vowel nasalization. These latter two observations are quite invariant across languages and speakers, while the patterns of preceding vowel nasalization exhibit much more variability.

In the next chapter, I turn to a discussion of the duration-related hypotheses set forth in chapter 3. I also continue to address the issue of relative nasal-oral timing in NC sequences, based upon the acoustic data.

CHAPTER FIVE:
ACOUSTIC RESULTS

5.1 Introduction

In chapters 1 and 2, I illustrated that there are distinct NC patterns in phonology, and I posed the question of whether or not these patterns are reflected in the phonetics. In chapter 3, I considered several phonetic characteristics that may be of relevance in distinguishing a unary NC segment from an NC cluster: total duration of the NC sequence, degree of nasalization in the preceding vowel, and duration of the preceding vowel. The latter two factors were addressed in chapters 3 and 4, and now in chapter 5, I deal with the first—total duration of the NC sequence—and address the following two hypotheses:

H1: Unary NC segments are similar in duration to comparable unary segments in a language

H2: NC clusters are substantially greater in duration than comparable unary segments in a language

To address these hypotheses, I present the duration data from the four languages discussed in chapter 2, section 2.2, for which experimental data were collected (as described in chapter 3, section 3.2). As will be seen, the data reveal that both hypotheses are true, and therefore that NC clusters are substantially longer than unary NC segments. Since it is not possible to compare the duration of a unary and cluster NC within the same language (not in the languages in this study and not, arguably, in any language, as discussed in chapter 2, section 2.1), it is necessary to compare unary NC sequences to other sounds within the same language, and to compare NC clusters to other sounds within the same language, and then to relate these comparisons across the languages (as reflected in the statement of the separate hypotheses).

The comparative relationship found to be the most important in this study is that between the duration of a plain nasal and an NC sequence at the same place of articulation. As will be seen, in a language with unary NCs, the total duration of the sequence is essentially the same as the duration of a plain nasal, whereas in a language with NC clusters, the duration of the sequence is significantly longer than a plain nasal. The spectrograms on the following page illustrate this comparison in Tamambo (figure 5.1), where the NC sequence constitutes a prenasalized stop, and Manado Malay (figure 5.2), where the sequence constitutes a heterosyllabic cluster. In these and all following spectrograms, the target sounds are segmented and labeled, but the closures and releases are not, given their brevity. When comparing spectrograms in a figure, tokens are aligned at the beginning of the target segment in each and time scales are identical.

As seen in the Tamambo data in figure 5.1, containing representative tokens of /ta**n**o/ 'garden' and /ta$^{\mathbf{n}}$**d**a/ 'to look up' by T5, the plain /n/ and prenasalized stop /^{n}d/ are very similar in duration, 78 and 77 ms, respectively. When the /nd/ forms a cluster, however, as it does in Manado Malay, illustrated in figure 5.2 with representative tokens of /ta**n**a/ 'earth' and /ta**nd**a/ 'sign' by M4, the /nd/ sequence is much longer in duration than the plain /n/, 106 ms and 59 ms, respectively.

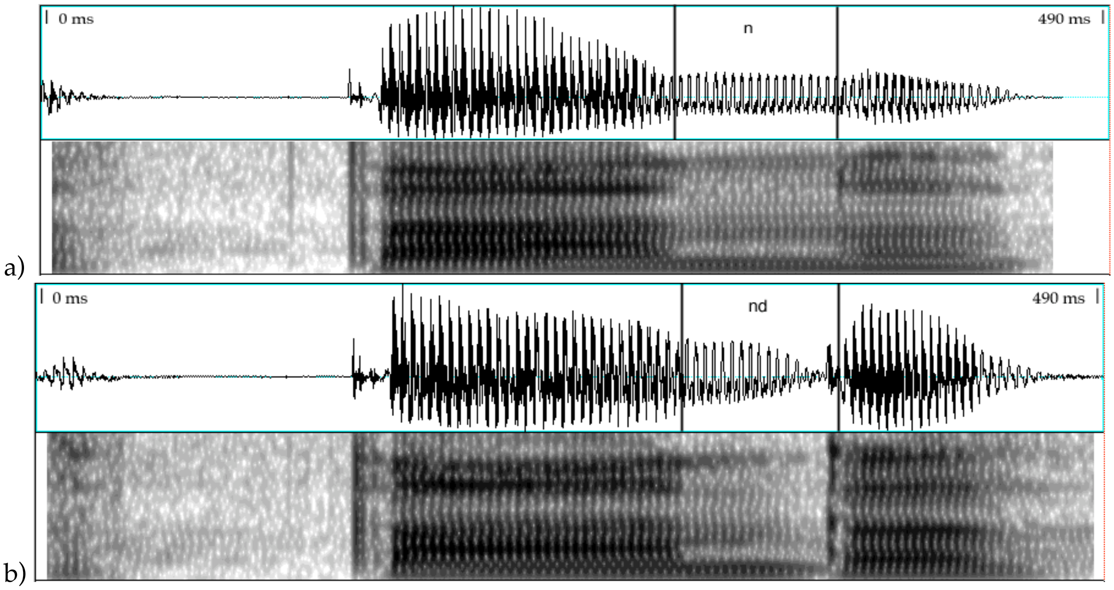

Figure 5.1: Tamambo. Representative waveforms and spectrograms of /tano/ ‘garden’ (a) and /ta^{n}da/ ‘to look up’ (b) by T5. Window length is 490 ms each. Frequency on the Y-axis is 0-5000 Hz.

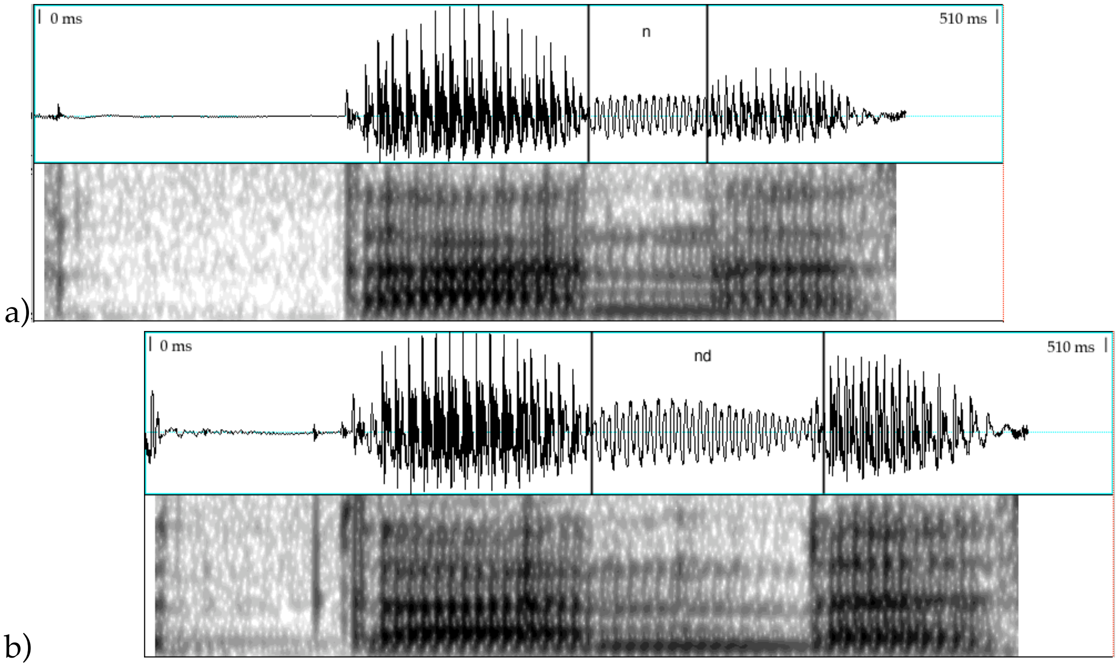

Figure 5.2: Manado Malay. Representative waveforms and spectrograms of /tana/ ‘earth’ (a) and /tanda/ ‘sign’ (b) by M4. Window length is 510 ms each. Frequency on the Y-axis is 0-5000 Hz.

In addition to comparing the duration of a plain nasal with that of an NC sequence, one can compare the duration of a plain voiced stop. While the data reveal that plain voiced stops are also significantly shorter than NC clusters in the cluster languages, this comparison is not available for the unary NC languages, which lack plain voiced stops. Another possible comparison, that between the duration of a plain voiceless stop and an NC sequence at the same place of articulation, may be a valuable comparison in the case of NC̥ sequences but is less informative when investigating the status of the voiced NC sequences, given the mismatch in voicing (and related durational differences, to be discussed), and therefore does not necessarily yield consistent or informative results. Nonetheless, comparisons will be made between the durations of each of the simple segments with each of the NC sequence-types where available. It will become clear throughout the presentation of data, however, that it is the N:NC relationship that is the most reliable and informative and offers the best cross-linguistic comparisons.

Another reason for focusing primarily on the duration relationship between plain nasals and NC sequences is that for all voiced NC sequences—regardless of phonological status—essentially the entire closure is nasal, followed by only a very brief oral portion, as seen in the above spectrograms and also discussed in chapter 4, section 4.3. Therefore, the duration of the nasal closure is of particular interest. The comparison between a plain nasal and an NC̥ sequence is also discussed to some degree, although it is not as interesting to the primary topic given that all NC̥ sequences in the data are clusters (with no unary examples for comparison). Throughout this chapter, the duration relationship between a plain nasal and an NC sequence is discussed in terms of the ratio N:NC, where N=1.

Although ratios and averages are used in later discussion, for ease of exposition when comparing the languages, the full range of data from each speaker of each language is presented, in box plots, as described in chapter 3, section 3.2.5. The reason for including the data in such detail is to reveal the variation between the speakers of a language, as well as across a single speaker's repetition of the same form. Studies that look only at averages may obscure the results and miss important observations. Bar graphs displaying the average durations of the component parts of the NC sequences and corresponding plain segments are also presented. To allow for easy visual comparison across figures, all box plots in this chapter are on a scale from 0 to 300 ms, while all bar graphs are on a scale from 0 to 260 ms. (Note that in some figures, certain phonetic fonts were unavailable, and necessary substitutions are indicated in the figure labels.)

Alveolars are treated as the primary case. This is due to the fact that the largest number of NC contrasts in the data occur in this position, and because this is where the most consistent generalizations are observed. For this reason, the alveolar data are presented first for each language. The alveolar data are followed by data for bilabials, velars, and finally alveopalatal affricates. Data are generally presented for five speakers of Tamambo, six of Manado Malay and Pamona, and four of Erromangan. However, in some cases a speaker's data are not included in a certain section due to considerable labeling difficulties with the token set in question and subsequent unreliability. This is particularly true in the case of the velars, as discussed in chapter 3, section 3.2.5, and therefore the velar sections contain less data than the others. Before turning to the data, I present some expectations of durational variation in the following section.

5.1.1 Expectations of duration

When considering the acoustic data in this chapter, the primary interest is in the durational difference between plain segments and NC sequences. It is important to bear in mind, however, that not all of the observed durational differences will be due to unary-cluster distinctions; rather, many differences will reflect the inherent durational properties of segments (as well as other factors discussed in chapter 3, section 3.1.1). In this section, I briefly sketch some of the expected durational differences among segments and sequences—regardless of the status of the NC sequences. I use English as an example, a language in which all NC sequences are clusters, with data from Vatikiotis-Bateson (1984) (hereafter VB), discussed in chapter 3, section 3.1.2, and illustrative spectrograms that I produced.

Figure 5.3 below contains spectrograms of a minimal NC set (plain nasal, voiced stop, voiceless stop, NC̬ and NC̥), at the bilabial place of articulation. The bilabial place was chosen given that flapping at the alveolar place in English (discussed below) renders the alveolar set less useful. The following set, which includes some nonce forms, was chosen for illustration because this was also the set used in the VB study: *kammer*, *cabber*, *capper*, *camber*, *camper*. The window length is 520 ms in each frame.

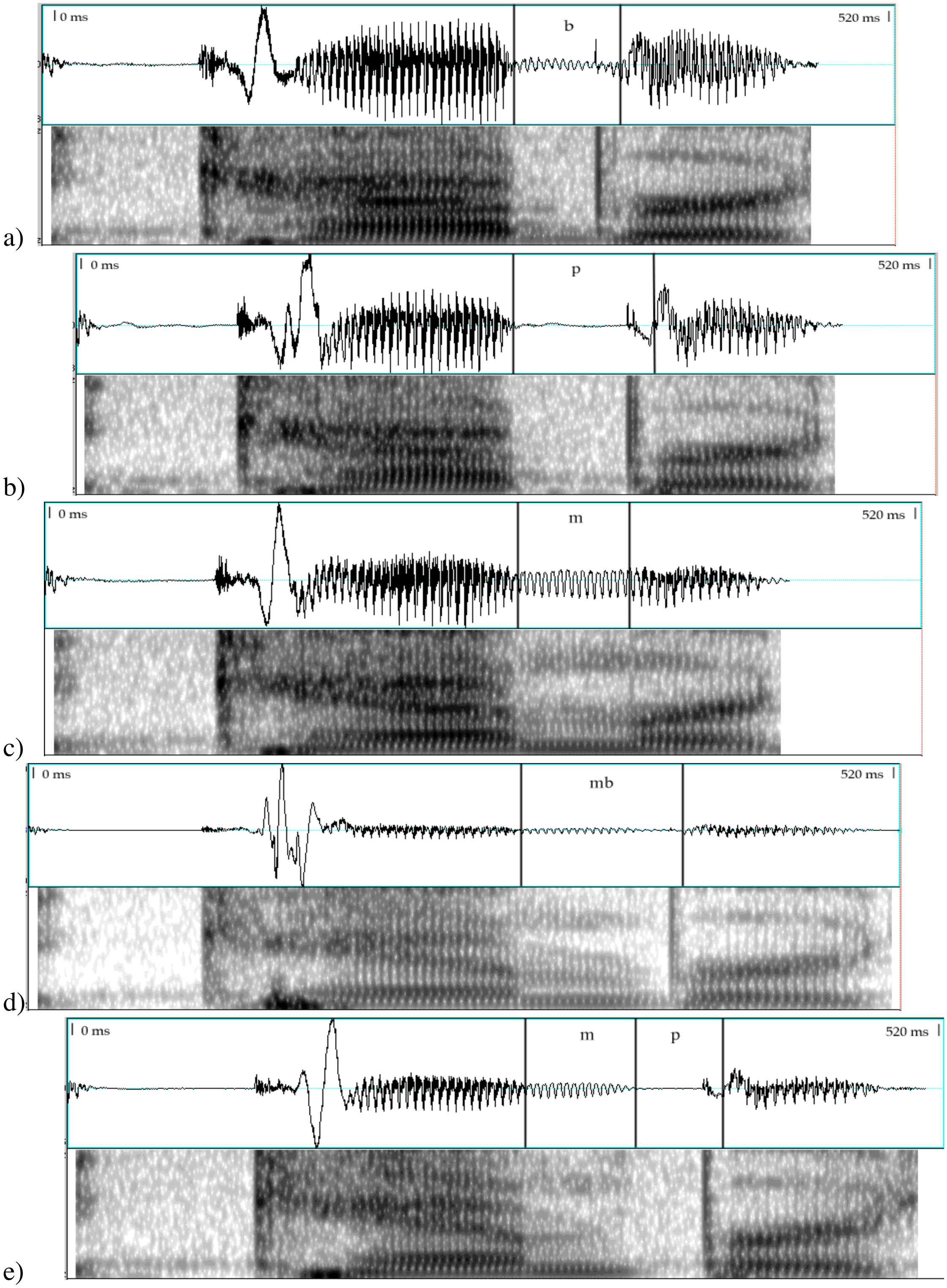

Figure 5.3: English. Representative waveforms and spectrograms of /kæber/ (a), /kæper/ (b), /kæmer/ (c), /kæmber/ (d), /kæmper/ (e). Window length is 520 ms each. Frequency on the Y-axis is 0-5000 Hz.

Spectrograms (a-c) contain single segments and (d-e) contain clusters. Note that within each group, the durations of the segments vary. First, voiceless consonants such as /p/ are generally longer than voiced consonants such as /b/ (84 versus 61 ms above, including releases). In the VB study, the mean duration of /b/ in this word was 53 ms across five repetitions for five speakers while the mean duration of /p/ was 95 ms (73 ms closure, 22 ms aspiration). Note also that while both segments have a burst, the aspiration on the voiceless segment is longer than the release on the voiced stop—18 versus 7 ms, respectively (a possible difference that will vary greatly depending upon the language). Plain nasals tend to be closer in duration to voiced stops than voiceless. The duration of /m/ above is 68 ms while the mean duration of /m/ in VB's study was 58 ms.

Second, the NC clusters in (d-e) are longer than the plain nasal or stops in (a-c). However, as discussed in chapter 3, section 3.1.1, the total duration is not equal to the combined durations of each plain segment. For example, in the above figure, the total duration of /mb/ is 97 ms, substantially longer than /m/ or /b/; it is not, however, the combined total of both (which would be 152 ms). In the VB study, the mean duration of /mb/ was 88 ms (greater than plain /m/—58 ms, or plain /b/—53 ms—but not the combined total of 111 ms). VB suggests that the shortening in the cluster, at least in the English case under investigation, may be due in part to speakers' maintenance of a relatively stable duration across words, regardless of the number of segments. Note also, given the inherent durational differences between voiced and voiceless stops, the total duration of /mp/ is much greater than /mb/—118 versus 97 ms. (In VB's study, the mean duration of /mp/ was 109 ms). The issue of the relative durations of nasal and oral closures in NC sequences is taken up in this chapter as well as chapter 6, section 6.2.

Finally, segments differ in duration based upon place of articulation. While the duration of the plain voiced bilabial above is 61 ms, the corresponding velar is 72 ms while the alveolar is 17 ms, as seen in the following spectrograms of *katter* and *kacker*. Alveolars in English are, of course, a complicated case given flapping—and therefore great reduction—in this environment (see e.g. Kahn 1976, Zue and Laferriere 1979, Riehl 2003 and references therein). However, they do highlight the point that many factors play a role in affecting duration.

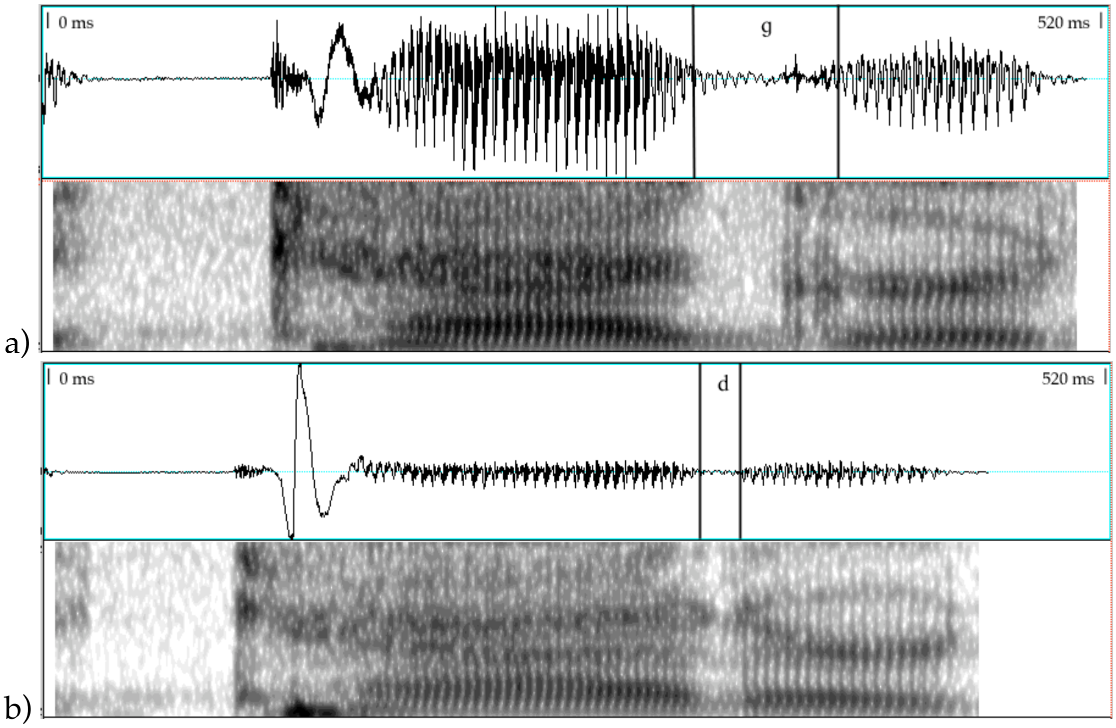

Figure 5.4: English. Representative waveforms and spectrograms of /kæger/ (a) and /kæder/ (b). Window length is 520 ms each. Frequency on the Y-axis is 0-5000 Hz.

The English data illustrate that segments and sequences have inherent differences in duration. If one segment or sequence is substantially shorter than another, this obviously does not necessarily mean that one is unary, while the other is a cluster (i.e. that /mb/ is shorter than /mp/ does not mean that the NC̥ sequence is a cluster while the NC̬ sequence is unary; that /t/ is roughly the same length as /mb/ does not mean that both are unary). Rather, it is important to bear in mind these inherent differences so that they do not interfere with the particular durational comparisons under investigation.

5.1.2 Overview of the chapter

The structure of the remainder of this chapter is as follows. The data from Tamambo, a language with unary NCs, are presented in section 5.2; followed by Manado Malay, a language with heterosyllabic NC clusters, in 5.3; Pamona, a language with tautosyllabic NC clusters, in 5.4, and finally Erromangan, a language with both unary and cluster NCs, in section 5.5. Each section contains duration data from minimal or near-minimal NC sets at each available place of articulation and word position, presented in box plots and bar graphs. Not all comparisons are available for all languages, since some languages lack certain segments or sequence-types in their inventories; those sets to be presented are indicated in table 5.1. A chapter summary is included in section 5.6.

Table 5.1: Data sets presented in chapter 5

Set type	**POA**	**Position**	**Tamambo**		**Manado**		**Pamona**		**Erro**	
			^{N}C	NC	^{N}C	NC	^{N}C	NC	^{N}C	NC
NC̬ stops	alveolar	initial	√			(√)		√	√	
		medial	√			√		√	√	
	bilabial	initial	√					√		
		medial	√			√		√		
	velar	initial						√		
		medial				√		√		
NC̥ stops	alveolar	initial						√		√
		medial				√		√		√
	bilabial	initial						√		
		medial				√		√		√
	velar	initial						√		
		medial				√		√		
NC affricates	alveopalatal	initial	√					√		
		medial	√			√		√		

5.2 Tamambo

As illustrated in chapter 2, section 2.2.1, the NC sequences in Tamambo are unary segments. Tamambo has a series of voiced prenasalized obstruents that is not in contrast with a series of plain voiced stops. At each place of articulation, therefore, there is a prenasalized stop, a plain nasal, and in most cases a plain voiceless stop (although there is no voiceless bilabial stop /p/).

Figure 5.5 below contains representative spectrograms of each of these three segment-types word-medially at the alveolar place of articulation: /t/ from /ta**t**a/ 'father', /n/ from /ta**n**o/ 'garden', and /^{n}d/ from /ta$^{\mathbf{n}}$**d**a/ 'to look up' by T3 (the last two being the same as those displayed in figure 5.1). The forms are aligned at the onset of the target segment in each. Window length is 490 ms in each frame.

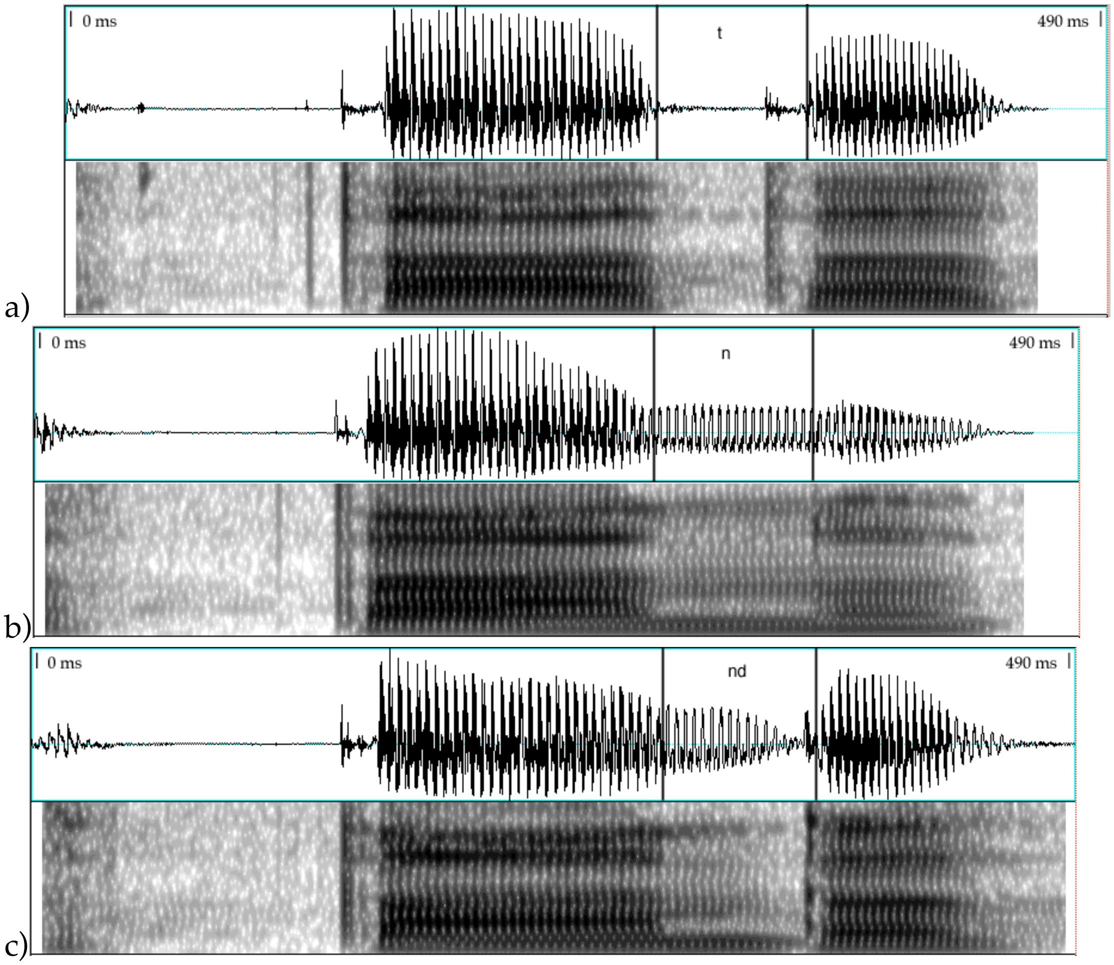

Figure 5.5: Tamambo. Representative waveforms and spectrograms of /tata/ 'grandfather' (a), /tano/ 'garden' (b), and /ta^{n}da/ 'to look up' (c) by T5. Window length is 490 ms each. Frequency on the Y-axis is 0-5000 Hz.

As seen in the above figure, the total durations of the /n/, /t/, and /^{n}d/ are about the same (78, 75, and 77 ms, respectively). Although patterns vary somewhat across the speakers, as will be seen, the generalization that the plain stops, plain nasals, and prenasalized stops are all of roughly the same duration holds throughout the Tamambo data (with some tendency for plain voiceless stops to be slightly longer than the others). The plain stops, such as /t/ above, usually include some period of aspiration (22 ms above, relatively long for the Tamambo data). Aspiration is included in the total duration values in the box plots, although the separate durations of oral closure and aspiration are displayed in the bar graphs at the end of the discussion of each place of articulation in each language. Given the topics under investigation here, nothing crucial hinges upon the inclusion or exclusion of aspiration in the total duration values.

In the following sections, I present the duration data for Tamambo. Minimal or near-minimal sets containing NC sequences in comparison with plain nasals and voiceless obstruents, are considered for alveolar and bilabial stops and for alveopalatal affricates (although there is no bilabial voiceless stop). Since the language does not contain plain voiced stops, these segments are obviously not included for comparison. Additionally, as there are no velar NC sequences in Tamambo, there is not a section on velars. Finally, the prenasalized labialized bilabial /^{m}b^{w}/ will not be included due to unreliable segmentation between the consonant release and following vowel.

The following data reveal that the duration of a unary NC sequence in this language is essentially the same as the duration of a corresponding plain nasal (with slight variation among speakers), at both the alveolar and bilabial places of articulation, and in both word-initial and medial position. In the case of the prenasalized affricate /^{n}dʒ/, however, the sequence is longer than a plain /n/, a difference attributed to the phonetic character of the sequence as articulated by these speakers (whereby the oral portion is affricated and devoiced), to be discussed. Data on the relative lengths of the component parts of NC sequences and voiceless stops are also included at the end of the discussion of each place of articulation.

5.2.1 Tamambo- Alveolars

The alveolar data in Tamambo are considered in this section. The following table contains the near-minimal set for the alveolars in initial position.

Table 5.2: Target words for alveolars in initial position in Tamambo

Target sound	Token	Gloss
/n/	/**n**ovu/	*n*, stonefish
/t/	/**t**ovu/	*n*, sugarcane
/^{n}d/	/$^{\mathbf{n}}$**d**ovo/	*v*, to be rotten

The duration data for the target sounds in the above words are in figure 5.6 below. Given that this is the first box plot contained in the thesis and that some readers may be unfamiliar with the format, a detailed explanation of the plot follows. (Please refer also to chapter 3, section 3.2.5.)

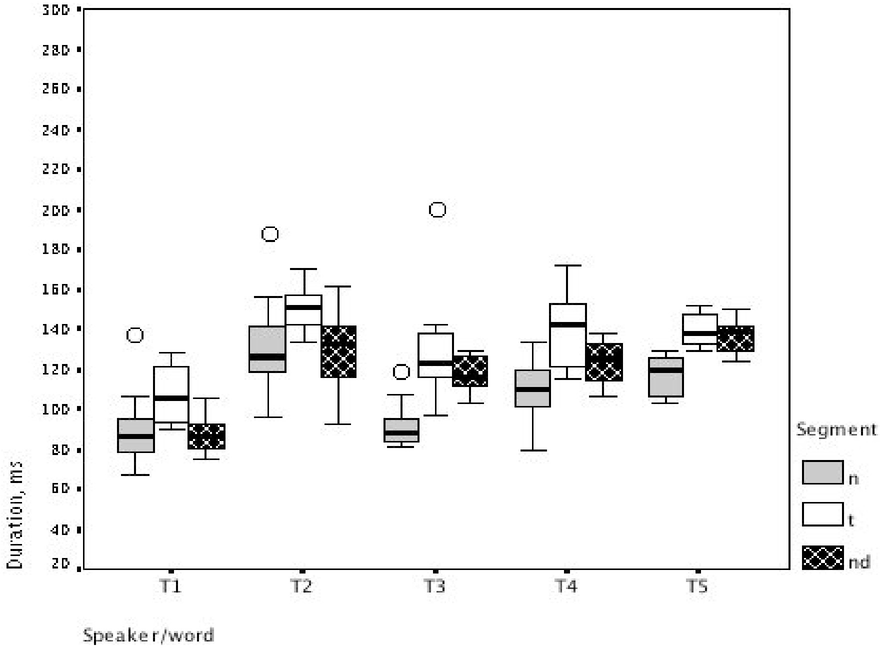

Figure 5.6: Tamambo. Duration of alveolars in initial position for ten repetitions (except: T2 /n/–9; T5 /n/–9). Difference between /n/ and /^{n}d/ significant at p≤.001 for T3, T5; p≤.05 for T4.

Figure 5.6 contains data for five speakers, identified along the horizontal axis (T1-T5). For each speaker, there are duration data for three target segments—/n/, represented by a light gray box, /t/, represented by a white box, and /^{n}d/, represented by a black box with a white checked pattern—for ten repetitions (unless indicated otherwise in the figure label).[1] The vertical axis represents duration in milliseconds (0 to 300 ms). The span of each box represents the interquartile range or middle 50% of the data. For example, for T1, this range for /^{n}d/ tokens falls between 78 ms and 96 ms in duration. The black line in the middle of a box represents the median value. For example, the median /n/ value for T2 is 125 ms. The whiskers extending from the boxes represent the middle 75% of the data, or all of the non-outlying data. For example, this range for T4's /t/ tokens is from 115 to 175 ms. The circles represent mild outliers (1.5 to 3 times the interquartile range). For example, T3 has one /^{n}d/ token with a duration of 200 ms. Extreme outliers (more than 3 times the interquartile range) are represented by an asterisk; there are none in this plot.

A general overview of the data reveals that there is considerable overlap between the durations of the different segment-types for all of the speakers. /n/ and /^{n}d/ are the shortest segments, with some speakers showing a slightly shorter /n/, and /t/ is the longest. Recall that aspiration is included in the total duration measurements for the voiceless stops. Regarding the relationship between /n/ and /^{n}d/, for two speakers (T1 and T2), the durations of /n/ and /^{n}d/ show no significant difference. The three other speakers exhibit

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[1] Note that missing tokens and statistical significance are indicated in the figure label rather than within the box plot (for this figure and all following figures), given the abundance of data in the plot and difficulty of visually presenting all necessary information within the graphic.

a slightly longer /ⁿd/, the largest difference being for T3 whose average /n/ is 85 ms and /ⁿd/ is 120 ms. However, although the differences in means are significant (as indicated in the figure label), the magnitude of these differences, even for T3, is fairly small—as will be seen when comparing Tamambo with the other languages—and for all speakers, there is considerable overlap between the two categories. These latter two points are very important. As discussed in chapter 3, section 3.2.5.1, significantly different means are not necessarily relevant to the discussion of unary vs. cluster NC distinctions, while the magnitude of these differences, and the overlap between categories, will be shown to be important. To summarize, /ⁿd/ in initial position in Tamambo is either of comparable length to, or slightly longer than, /n/, an observation consistent with the hypothesis that unary NC sequences are the duration of comparable single segments.

The minimal set for alveolars in medial position is in the following table 5.3, with duration data in figure 5.7.

Table 5.3: Target words for alveolars in medial position in Tamambo

Target sound	Token	Gloss
/n/	/ta**n**o/	*n*, garden
/t/	/ta**t**a/	*n*, paternal grandmother
/ⁿd/	/ta**ⁿd**a/	*v*, to look up

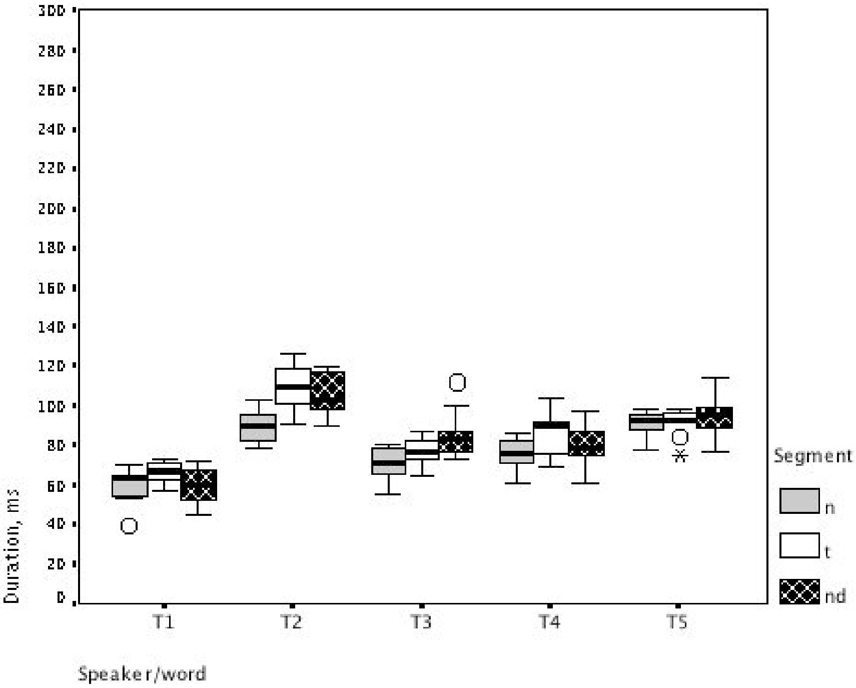

Figure 5.7: Tamambo. Duration of alveolars in medial position for ten repetitions. Difference between /n/ and /^{n}d/ significant at p≤.001 for T2; p≤.01 for T3.

As seen in the above plot, there is a great deal of overlap between the durations of the three segment-types for all speakers in medial position, even more than that observed in initial position. The duration of /n/ and /^{n}d/ is comparable for four speakers, who show no statistically significant difference between the two groups. For a fifth speaker, T2, the duration of /^{n}d/ is slightly longer than the duration of /n/ (an average of 100 ms and 90 ms, respectively), a difference that, although significant, is still relatively small. Note, however, that T2 did not show a significant difference in initial position. Note also that T3, who exhibited the most substantial difference in initial position, shows only a very small one here. In brief, /n/ and /^{n}d/ in medial position have the same or very similar durations for all speakers, consistent with the hypothesis that these unary sequences are the duration of simple segments. Only a single speaker (T3) exhibits a statistically significant difference between the average durations of /n/ and /^{n}d/ in both word positions.

The durations of the component parts of the /^{n}d/ sequences and corresponding plain segments are shown in the following bar graph.

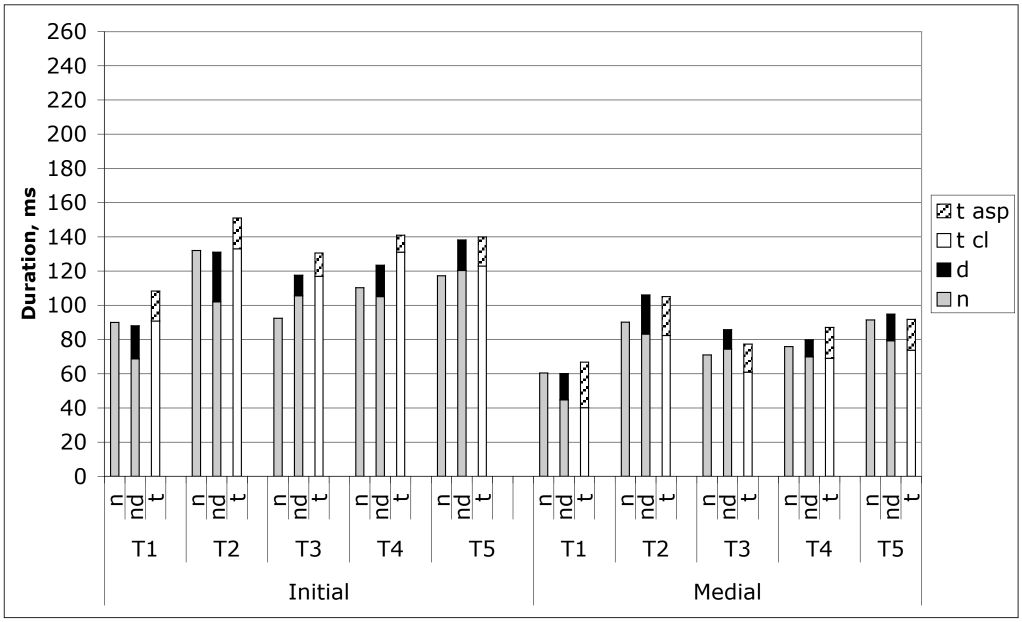

Figure 5.8: Tamambo. Average durations of component parts of alveolars in initial and medial position, based upon data in figures 5.5 and 5.6. [Note: "nd" represents /^{n}d/.]

As the data from all of the speakers reveal, the oral portion of an /^{n}d/ sequence comprises only a small amount of the overall duration of the sequence, an average range across speakers of 10-29 ms. Since the durations of /n/ and /^{n}d/ are usually comparable, the effect is that the duration of the nasal portion of /^{n}d/ is generally slightly shorter than that of /n/, as illustrated by T1, for example. When /^{n}d/ is somewhat longer than /n/, the average nasal portion of /^{n}d/ is comparable in length, or slightly longer than, /n/, as seen, for example, in

T3's data. The oral portion of /^{n}d/ is similar in length to the aspirated portion of /t/, the latter of which has an average range across speakers of 10-26 ms.

5.2.2 Tamambo- Bilabials

The bilabial data for Tamambo are considered in this section. Since there is no /p/ in Tamambo, there are no plain stops for comparison. Table 5.4 contains the minimal set for bilabials in initial position. Duration data follow in figure 5.7.

Table 5.4: Target words for bilabials in initial position in Tamambo

Target sound	Token	Gloss
/m/	/**m**aka/	*n*, mud
/^{m}b/	/**^{m}b**aka/	*n*, bow (weapon)

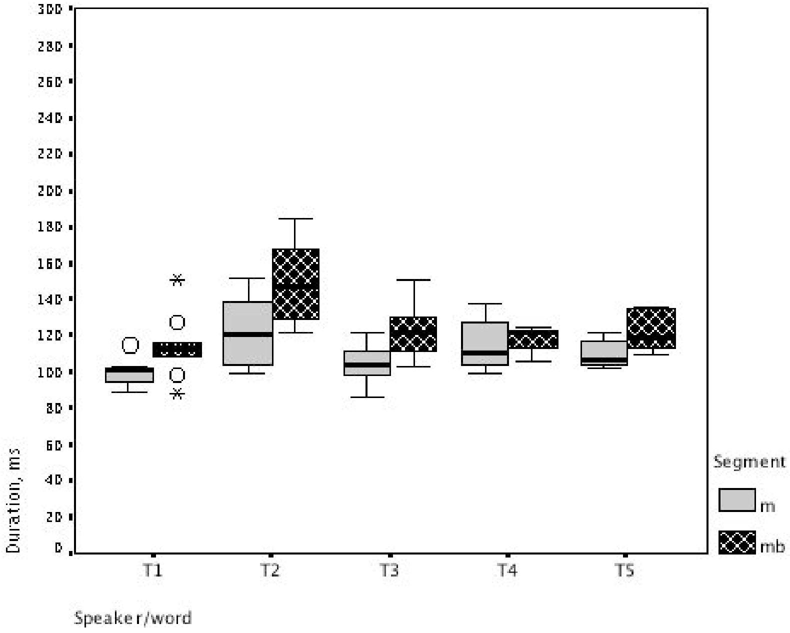

Figure 5.9: Tamambo. Duration of bilabials in initial position for ten repetitions (except: T1 /m/–9; T4 /^{m}b/–9). Difference between /m/ and /^{m}b/ significant at p≤.01 for T3, T5; p≤.05 for T1, T2.

As seen in the above plot, the duration of /m/ and /^{m}b/ in word-initial position is quite comparable for all speakers. Although there is a tendency for /^{m}b/ to be slightly longer than /m/, a difference that is statistically significant for four speakers, the degree of difference is nonetheless small, and considerable overlap is seen in all cases. In short, /m/ and /^{m}b/ are of similar duration for all speakers, consistent with the hypothesis that unary NC sequences are the duration of simple segments.

The minimal set for bilabials in medial position is in table 5.5 below. Duration data for these forms follow in figure 5.10.

Table 5.5: Target words for bilabials in medial position in Tamambo

Target sound	Token	Gloss
/m/	/ta**m**a/	*n*, father
/^{m}b/	/ta**^{m}b**a/	*v*, to bump into

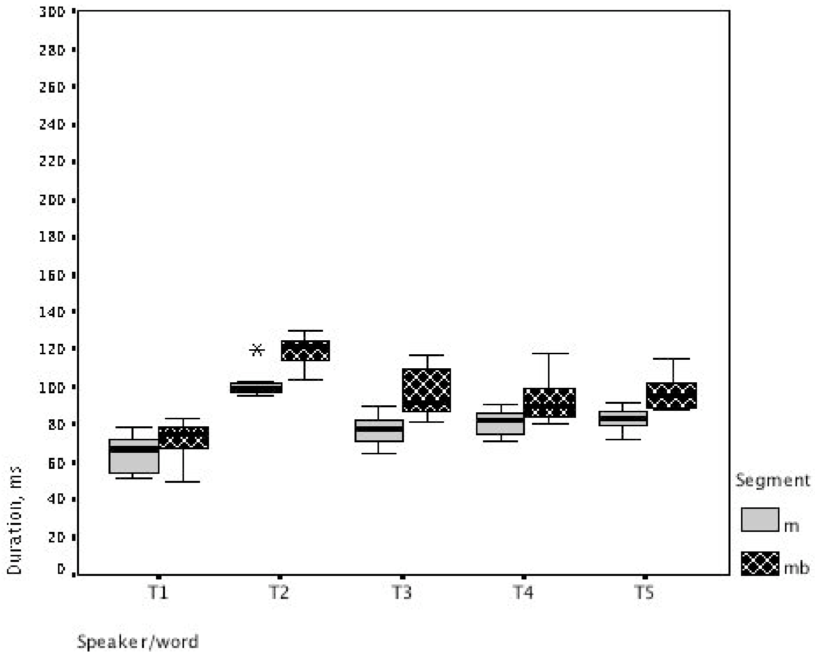

Figure 5.10: Tamambo. Duration of bilabials in medial position for ten repetitions (except T5 /m/–9). Difference between /m/ and /^{m}b/ significant at p≤.001 for T2, T3; p≤.05 for T4, T5.

As seen in the above plot, the durations of /m/ and /^{m}b/ are quite similar for all speakers, with a tendency for /^{m}b/ to be slightly longer than /m/, a difference that is significant for four speakers. In all cases, however, this degree of difference is small, and there is some overlap between the categories. In general, the duration of /^{m}b/ in medial position is either comparable to, or slightly longer than, /m/, for all speakers, consistent with the hypothesis that unary NC sequences are roughly the length of simple segments.

The following bar graph illustrates the durations of the component parts of the /^{m}b/ sequences in both initial and medial position.

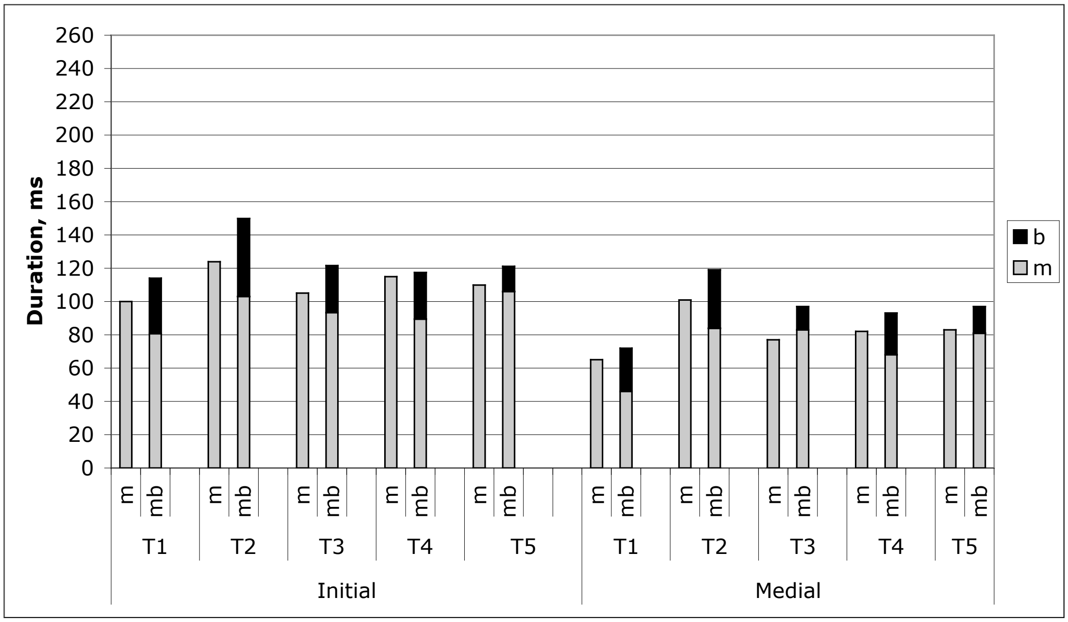

Figure 5.11: Tamambo. Average duration of component parts of bilabials in initial and medial position, based upon data in figures 5.9 and 5.10. [Note: "mb" represents /^{m}b/.]

As seen above, the majority of an /^{m}b/ closure is nasal, while the oral portion comprises approximately the last one-fifth to one-third of the total duration, an average range across speakers of 14-46 ms (although note that this high end of 46 ms, for T2, is unusually long across all of the speakers and languages investigated). Since the average duration of /m/ and /ᵐb/ is quite similar, the result is generally that the nasal portion of /ᵐb/ is shorter than /m/, as seen for example in T4's data. Even when /ᵐb/ is significantly longer than /m/, as in T2's initial data, the nasal portion of /ᵐb/ is shorter than plain /m/. For speaker T5, on the other hand, the nasal portion of /ᵐb/ is comparable in length to plain /m/. In no case is the average nasal portion of /ᵐb/ longer than plain /m/ (except for a negligible difference of several milliseconds for T3). Overall, the oral portion of the bilabial sequences is longer than it is for the alveolars. This difference is likely the cause of the slightly greater difference in total duration between N and NC in the case of bilabials as compared to alveolars.

5.2.3 Tamambo- Affricates

This section contains duration data for the prenasalized affricate /ⁿdʒ/. This segment is characterized as a voiced palatal stop by Jauncey (1997) and Riehl and Jauncey (2005), based upon data from the broader Tamambo-speaking population, both in terms of production and in terms of symmetry in the phonological inventory. However, many speakers produce this stop as an affricate, including all of the young adult speakers living in Vila who were recorded for this project, and therefore it is classified in the present study as an affricate.

It is not surprising that the palatal stop has undergone a change and is articulated as an affricate by these speakers. Palatal segments have been shown to have longer constrictions than sounds at other places of articulation (Keating 1988), and it is common for the release of this longer constriction to produce frication, resulting in an affricate. For the young urban speakers recorded for this project, not only is the sound invariably an affricate, but the oral portion is usually devoiced. Given the fricated release, this devoicing is not surprising. Frication is difficult to produce when the vocal folds are vibrating, as they impede the high volume of airflow through the glottis that is needed to produce the turbulence (Johnson 1997). The production of the prenasalized palatal stop as affricated and as devoiced by these speakers raises two issues for the present study. First, this sound must be considered with regard to the claim that prenasalized voiceless stops do not exist; this is addressed in chapter 6, section 6.4.2 (where I will argue that the devoicing is phonetic, and that crucially, a unary segment cannot be phonologically specified as voiced). Second, the consequences of this production on the expectations about the duration relationship between plain nasals and prenasalized stops must be addressed.

Three related factors make it likely that this prenasalized sound in Tamambo will be longer than a plain nasal: the naturally longer palatal constriction (as above), the affricated release (as affricates are generally longer than stops, given the frication being substantially longer than aspiration, as will be seen), and the voiceless oral portion (as voiceless obstruents are generally longer than voiced, as seen for English, for example, in section 5.1.1). Therefore, we might predict that /ⁿdʒ/, as produced by these speakers, will be longer than a plain nasal—for reasons unrelated to phonological structure—and this is in fact the case, as will be seen. In addition, given the lack of plain palatal nasals in Tamambo, the sequence is compared to a plain alveolar nasal in this study. This mismatch in place of articulation will also likely contribute to a greater duration ratio between the plain nasals and the NC sequences, as palatals are longer than alveolars. Given these issues, the duration data from this sequence will be more complicated to interpret with regard to the claim that unary NCs are the length of single segments.

Table 5.6 contains the minimal set for the prenasalized affricate in initial position. Note that the words containing the target sounds /n/ and /t/ are also those used in the initial alveolar box plots, and the data are repeated from above. Duration data follow in figure 5.12.

Table 5.6: Target words for affricate in initial position in Tamambo

Target sound	Token	Gloss
/n/	/**n**ovu/	*n*, stonefish
/t/	/**t**ovu/	*v*, to call out
/s/	/**s**ova/	*a*, asthmatic
/ⁿdʒ/	/**ⁿdʒ**ovi/	*v*, to fall

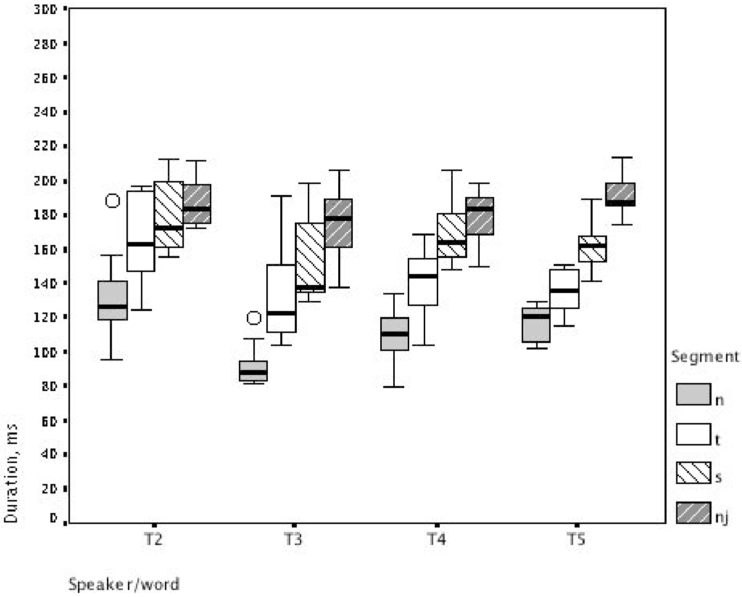

Figure 5.12: Tamambo. Duration of NC alveopalatal affricate and alveolars in initial position for ten repetitions (except: T2 /ⁿdʒ/–8; T3 /t/–9, /s/–9; T5 /t/–9, /s/–9, /ⁿdʒ/–8). Difference between /n/ and /ⁿdʒ/ is significant at $p \leq .001$ for all speakers. [Note: “nj” represents /ⁿdʒ/.]

As seen in the above plot, /n/ is the shortest segment for all of the speakers, while /ⁿdʒ/ is either the longest segment or as equally long as /s/, depending upon the speaker. The duration of /t/ falls in between. (Data from T1 was excluded due to segmentation difficulties.) Regarding the relationship between /n/ and /ⁿdʒ/, the duration of /ⁿdʒ/ is significantly longer than plain /n/ for all of the speakers, with no overlap between the groups. /ⁿdʒ/ forms a unary segment and is therefore expected to be comparable in duration to other single segments in the language (as seen with the alveolars and bilabials in the previous sections); however, as discussed above, given no plain palatal segments for comparison, and given the voiceless character and affricate manner of the segment (both of which result in increased duration), it is not necessarily productive to make comparative generalizations involving its length.

Table 5.7 contains the minimal set for /ⁿdʒ/ in medial position in Tamambo. Note that the words containing target /n/ and /t/ are the same as those used in the medial alveolar plot. Duration data for these sounds follow in figure 5.13.

Table 5.7: Target words for affricate in medial position in Tamambo

Target sound	Token	Gloss
/n/	/ta**n**o/	*n*, garden
/t/	/ta**t**a/	*n*, paternal grandmother
/s/	/ta**s**i/	*n*, younger brother
/ⁿdʒ/	/ta**ⁿdʒ**i/	*v*, to sharpen to a point

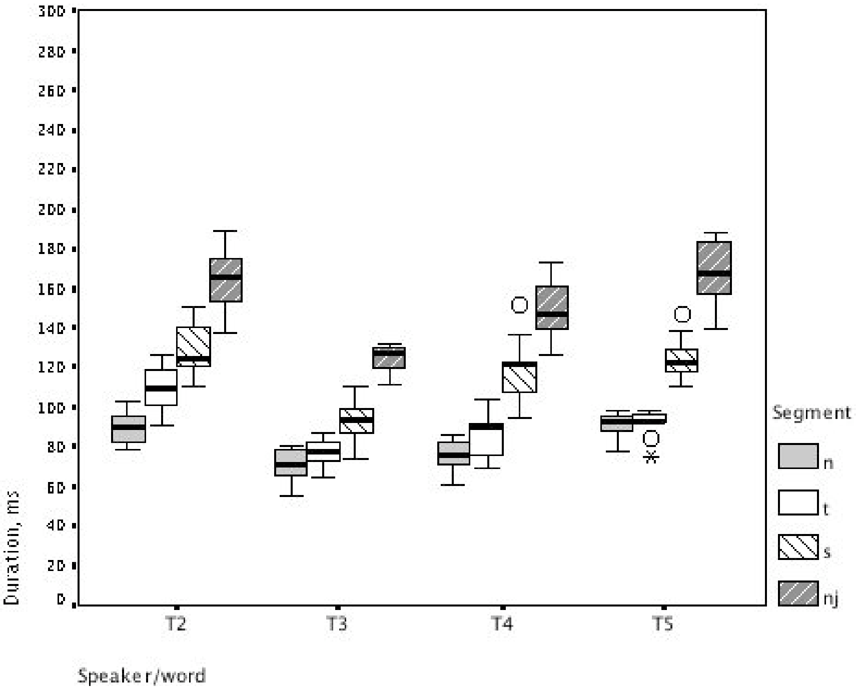

Figure 5.13: Tamambo. Duration of NC alveopalatal affricate and alveolars in medial position for ten repetitions. Difference between /n/ and /^{n}dʒ/ is significant at p≤.001 for all speakers. [Note: "nj" represents /^{n}dʒ/.]

As seen above, /n/ is either the shortest segment for each speaker, or equally as short as /t/. The longest segment is /^{n}dʒ/, with the duration of /s/ falling in between. Compared to initial position, the duration ranges for each segment are narrower, and there is less overlap between /^{n}dʒ/ and the shorter segments. Regarding the relationship between the plain nasal and the NC sequence, the total duration of /^{n}dʒ/ is much longer than a plain alveolar /n/ for all of the speakers, a difference that is significant for all subjects, with no overlap between groups. As mentioned in the above discussion, however, this difference should be attributed in part to the prenasalized segment having a devoiced oral closure and an affricate manner, both of which increase duration. This increased length should therefore not necessarily be interpreted as evidence against H1 (that unary NCs are the length of plain segments). Furthermore, as will be seen when comparing the data from other languages, the N:NC ratio for the Tamambo affricate is still smaller than it is in languages where the sequence forms a cluster.

The durations of the component parts of /ⁿdʒ/ are contained the following bar graph, compared with the alveolars /n, t, s/.

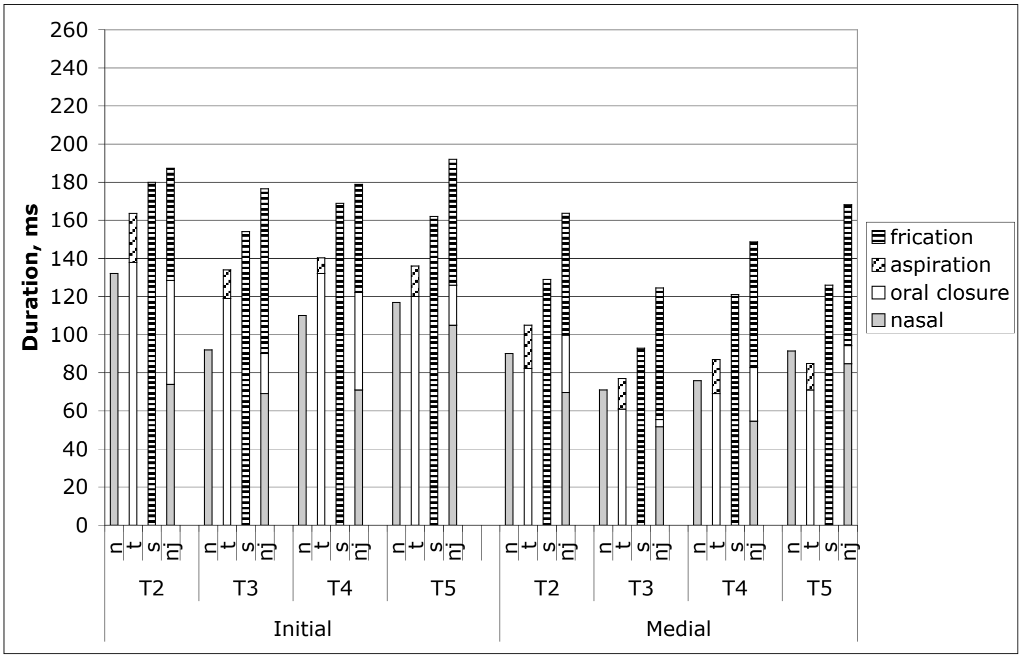

Figure 5.14: Tamambo. Average durations of component parts of NC alveopalatal affricate and plain alveolars in initial and medial position, based upon data in figures 5.12 and 5.13. [Note: "nj" represents /ⁿdʒ/.]

For most of the speakers, the nasal closure portion of the NC sequence is substantially shorter in duration than a plain nasal, more so than for the voiced prenasalized stops observed in previous sections (although the place of articulation differs between N and NC in this comparison). Aside from this similarity, however, there is a great deal of variation between speakers. In particular, speakers differ in the relative amounts of oral closure and fricated release in the /ⁿdʒ/ sequence. In the case of T2 and T4, for example, the oral closure and release portions are roughly the same duration in medial position, while the oral closure is somewhat shorter in initial position yet still comprises a substantial portion of the total duration. For T3 and T5, however, the closure portion of the oral phase is relatively small, with most of the oral portion consisting of a fricated release. This sort of variation between speakers is not observed when comparing relative amounts of nasal closure to oral closure in a prenasalized stop, or comparing oral closure to aspirated release in voiceless stops, both of which remain quite consistent across speakers. Figure 5.15 below illustrates the range of variation in the realization of /ⁿdʒ/ with waveforms and spectrograms of /ta**ⁿdʒ**i/ by T2 and T3.

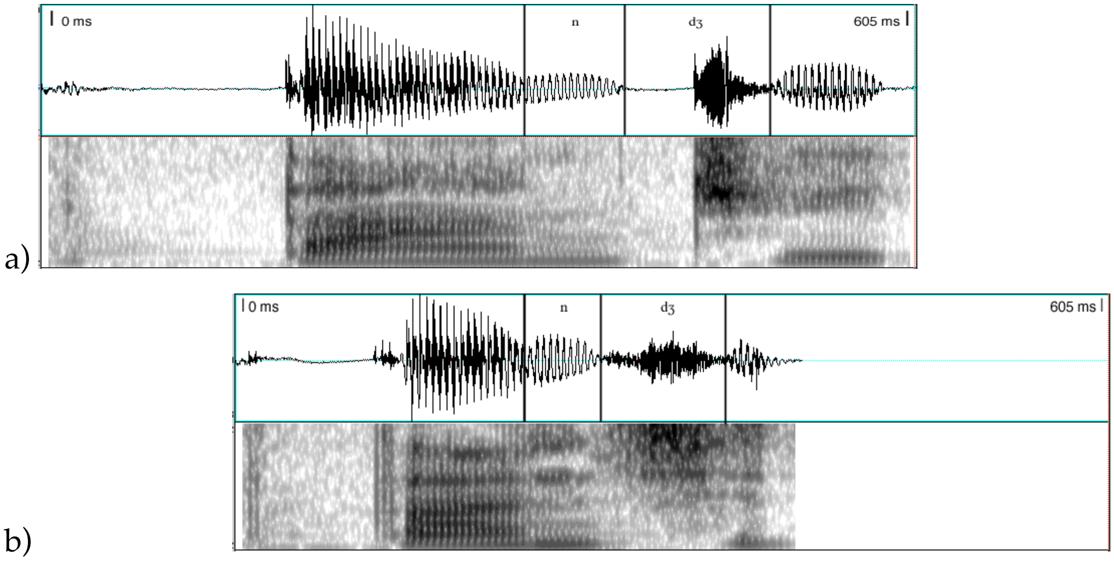

Figure 5.15: Tamambo. Representative waveforms and spectrograms of /taⁿdʒi/ by T2 (a) and T3 (b). Window length is 605 ms each. Frequency on the Y-axis is 0-5000 Hz.

As seen above, in T2's token (a), the prenasalized segment consists of a nasal closure (71 ms), followed by a clear oral closure (56 ms), and then a fricated release (63 ms). T3's token (b), however, contains a segment consisting of a nasal closure (50 ms) followed by a fricated release (82 ms), with no oral closure. Although the speakers themselves vary in the articulation of this segment across repetitions, for the most part, T2’s tokens tend to have clear oral closures, while T3’s tokens tend to have no oral closures, or much briefer oral closures. (Regarding the other two speakers, T4 tends to have substantial oral closures, while T5 has only brief oral closures.) As can be seen above, T2’s rate of speech was slower in the recording task than T3’s; however, the rate of speech does not correlate with the articulation of the prenasalized stop, at least in terms of whether or not speakers produce an oral closure.

5.2.4 Tamambo summary

As stated in the beginning of the chapter, the most relevant difference found in this study between unary NC sequences and NC clusters is in the relative duration difference between plain nasals and NC sequences in a given language. In the case of Tamambo, where NC sequences are unary prenasalized stops, we find that—for both the alveolars and bilabials—the durations of plain nasals are comparable to the total durations of the prenasalized stops, in both initial and medial position. Although there are slight duration differences in some cases, a comparison with data from other languages later in the chapter will reveal that these differences in Tamambo are relatively small. In the case of the prenasalized alveopalatal affricate, the total duration of the sequence is much greater than that of a plain nasal. However, this difference may be attributed to the devoiced and affricated nature of the oral portion, factors which result in greater duration, as well as to the lack of plain palatal nasals with which to make an accurate comparison;

these data therefore should not be viewed as evidence against H1 (that unary NCs are the length of comparable unary segments). Furthermore, as will be seen in later discussion, the N:NC ratio for this sequence in Tamambo is still much smaller than it is in Manado Malay, a language where the sequence is clearly a cluster.

The results in this section can be summarized by comparing the ratios of plain nasals to NC sequences for each of the cases, as in the following table 5.8. These ratios will be used to characterize the Tamambo data in comparative discussions of the different languages in the following chapter.

Table 5.8: Tamambo. N:NC ratios, N:NC; N=1, NC=X

Unary ^{N}C̬	**Alveolar**		**Bilabial**		**Affricate**	
	Initial	Medial	Initial	Medial	Initial	Medial
T1	1.1	1	1.2	1.1	---	---
T2	1.3	1.2	1.2	1.2	1.4	1.8
T3	1.1	1.2	1.2	1.3	1.9	1.8
T4	1.2	1	1	1.1	1.6	2
T5	1	1	1.1	1.2	1.6	1.8
Average	**1.1**	**1.1**	**1.1**	**1.2**	**1.6**	**1.9**

5.3 Manado Malay

As illustrated in chapter 2, section 2.2.2, the NC sequences in Manado Malay form heterosyllabic clusters. The sequences occur with both voiced and voiceless obstruents, and are in contrast with plain voiced and voiceless obstruents. At each place of articulation under investigation, therefore, Manado Malay has plain nasals, plain voiced stops, plain voiceless stops, NC̬ sequences, and NC̥ sequences, as illustrated for the alveolar place in the following figure.

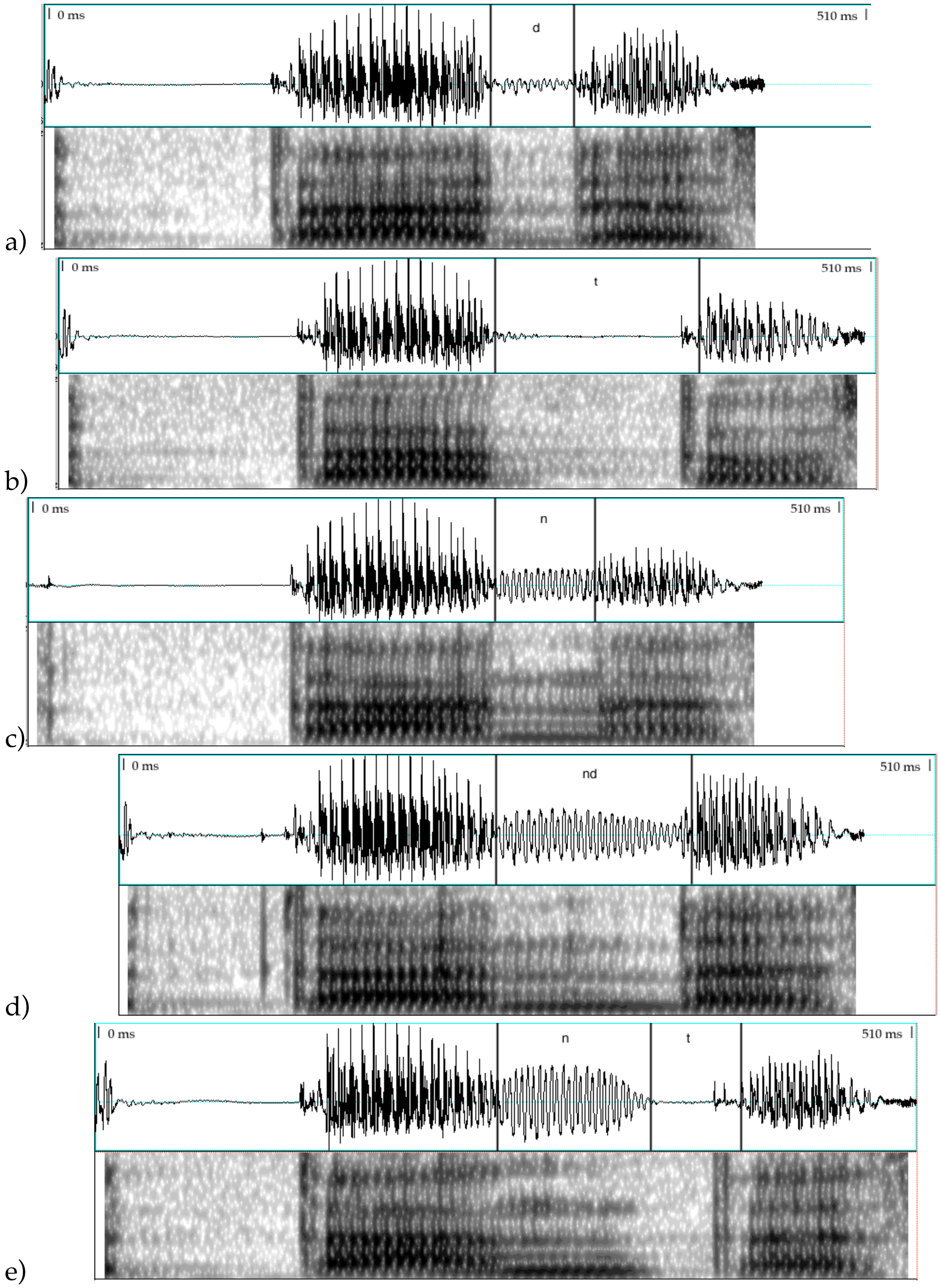

Figure 5.16: Manado Malay. Representative waveforms and spectrograms of /tada/ 'to stomp' (a), /tato/ 'tattoo' (b), /tana/ 'earth' (c), /tanda/ 'sign' (d), /tanta/ 'aunt' (e) by M4. Window length is 510 ms each. Frequency on the Y-axis is 0-5000 Hz.

Figure 5.16 contains representative waveforms and spectrograms of each segment and NC-type at the alveolar place of articulation in medial position, by M4: /n/ in /ta**n**a/ 'earth', /d/ in /ta**d**a/ 'to stomp', /nd/ in /ta**nd**a/ 'sign', /nt/ in /ta**nt**a/ 'aunt' (the /n/ and /nd/ forms being those in figure 5.2). Each token is aligned at the beginning of the target segment. Window length in each frame is 510 ms.

As can be seen in the figure, /d/ and /n/ are generally the shortest segments in Manado Malay (here at 52 and 59 ms, respectively). /t/ tends to be substantially longer than the other unary segments, 117 ms in the above figure, regardless of whether or not the brief period of aspiration (10 ms) is included in this measure (as it is here). The NC̬ cluster /nd/, which consists of a long nasal closure (longer than the plain nasal) followed by a short oral release, tends to be similar in duration to /t/ (here 106 ms). Finally, the NC̥ cluster /nt/ is substantially longer than all of the other segments or the voiced sequence, here 134 ms, and consists of a nasal closure (81 ms), oral closure (38 ms), and period of aspiration (15 ms).

The following sections contain the duration data for Manado Malay. Minimal or near-minimal sets containing both NC̬ and NC̥ sequences and corresponding plain nasals and stops at the alveolar, bilabial, and velar places of articulation are included, as well as a set including the NC̥ alveopalatal affricate cluster. Data for the corresponding NC voiced affricate cluster will not be included given considerable segmentation difficulties and the resulting unreliability of the data. Only medial sets will be presented, as Manado Malay lacks NC sequences word-initially (with the exception of one unusual form, to be discussed in the following section, with data in appendix C, figure

C.1). Additionally, data on a non-NC cluster /ks/ are included for comparison in appendix C, figure C.2, and will be referred to briefly in the discussion.

The data in this section reveal that the NC clusters in Manado Malay are in most cases significantly longer than corresponding plain nasals or stops. These differences are most pronounced at the alveolar and velar places of articulation, and less so at the bilabial place. In brief, the NC cluster data in Manado Malay look strikingly different from the unary NC data in Tamambo presented in the previous section.

5.3.1 Manado Malay- Alveolars

This section contains duration data for the alveolar NC set in medial position in Manado Malay. The target words are in table 5.9 below. Note that this set contains a plain voiced stop and an NC̥ sequence—two segment-types absent in the Tamambo data. Duration data for these target segments follow in figure 5.17.

Table 5.9: Target words for alveolars in medial position in Manado Malay

Target sound	Token	Gloss
/n/	/ta**n**a/	*n*, earth
/d/	/ta**d**a/	*v*, to stomp
/t/	/ta**t**o/	*n*, tattoo
/nd/	/ta**nd**a/	*n*, sign
/nt/	/ta**nt**a/	*n*, aunt

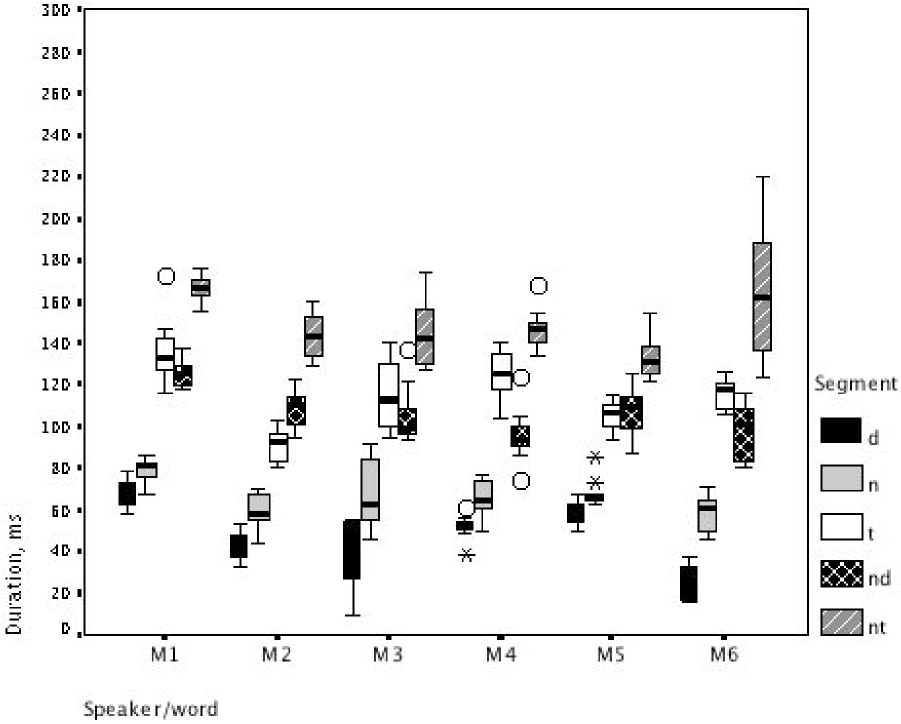

Figure 5.17: Manado Malay. Duration of alveolars in medial position for ten repetitions (except: M3 /nt/–9). Difference between /n/ and /nd/ significant at p≤.001 for all speakers.

For all of the speakers, /d/ is the shortest segment or sequence, followed by /n/, while /nt/ is the longest. (Recall that aspiration is included in the total duration measurements for voiceless stops.) The relative durations of /nd/ and /t/ vary depending upon the speaker. Regarding the relationship between /n/ and /nd/, the /nd/ is considerably longer than /n/ for all of the speakers. The difference is not only highly significant for all speakers, but it involves no overlap between the two categories for any of the speakers, supporting the hypothesis that NC clusters are longer than simple segments. /nd/ is also significantly longer than plain /d/. The /nt/ sequence is also much longer than its component parts in isolation, the plain /n/ or plain /t/.

Although NC sequences do not occur in initial position in Manado Malay, there is one exception. The word for 'no', /ɲandaʔ/, is sometimes truncated to [ndaʔ] (a shortened form commonly used in standard Indonesian). It is not clear how this unusual word should be regarded in the phonology of Manado Malay. Nevertheless, duration data for this word, compared to other truncated forms, were collected, and they reveal that initial /nd/ is substantially longer than plain /d/ and /n/ for all of the speakers. These data are included in appendix C, figure C.1, and will be briefly referred to in later discussion.

Data on the relative durations of the component parts of the sequences are presented in the following bar graph.

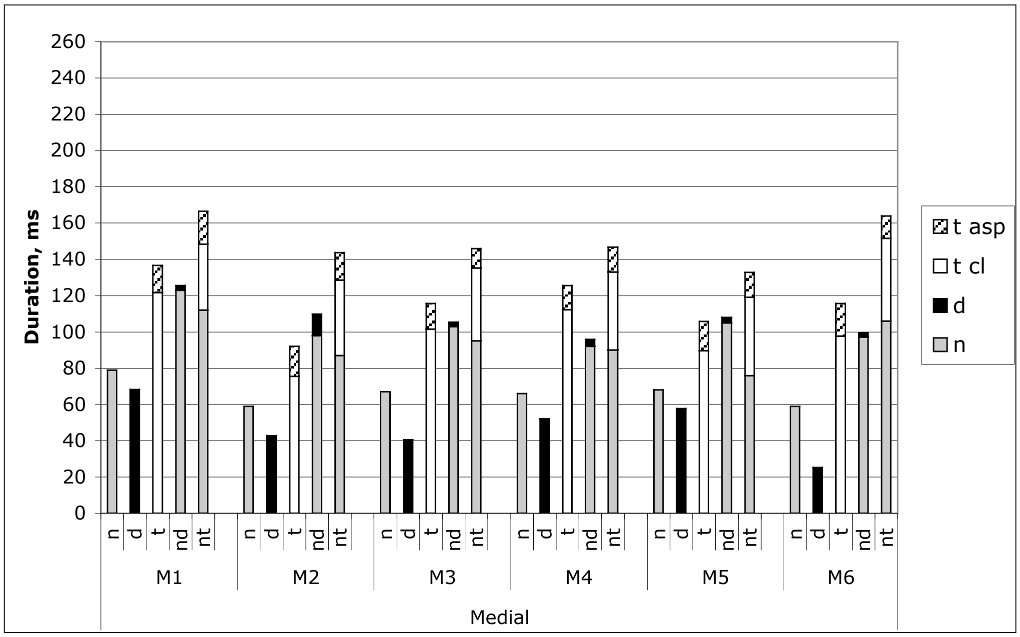

Figure 5.18: Manado Malay. Average durations of component parts of alveolars in medial position, based upon data in figure 5.16.

As seen above, almost the entire closure of an /nd/ sequence in Manado Malay is nasal, for all of the speakers, with only a very small portion comprising the oral component (usually just a brief release), an average range across speakers of 2-11 ms. Given the greater duration of /nd/ in comparison with /n/, the result is a much longer nasal closure for /nd/. Importantly, it is not the case that /nd/ looks simply like a combination of /n/ and /d/; rather it looks like an extended /n/, with a small oral release at the end. The /nt/ sequence also reveals a longer nasal closure than that found in a plain /n/, combined with an oral closure shorter than that found in a plain /t/; however, the oral portion of the NÇ̥ sequence is substantially longer than that of the NÇ̬ sequence. Regarding aspiration, the aspirated portion of a voiceless obstruent remains relatively steady despite changes in the length of the oral closure; for example, M1's /t/ and /nt/ both have an average of approximately 15 ms of aspiration, even though the total duration of plain /t/ is an average of 137 ms, while that of the /t/ in an /nt/ sequence is an average of only 54 ms. This generalization holds true for all of the speakers. The average duration of aspiration ranges across speakers from 10-18 ms.

5.3.2 Manado Malay- Bilabials

The near-minimal set for bilabials in medial position in Manado Malay is in table 5.10 below. Duration data follow in figure 5.19.

Table 5.10: Target words for bilabials in medial position in Manado Malay

Target sound	Token	Gloss
/m/	/ta**m**u/	*n*, guest
/b/	/ta**b**a/	*a*, patient
/p/	/ta**p**e/	*n*, fried taro dish
/mb/	/ta**mb**a/	*v*, to add
/mp/	/ta**mp**a/	*n*, place

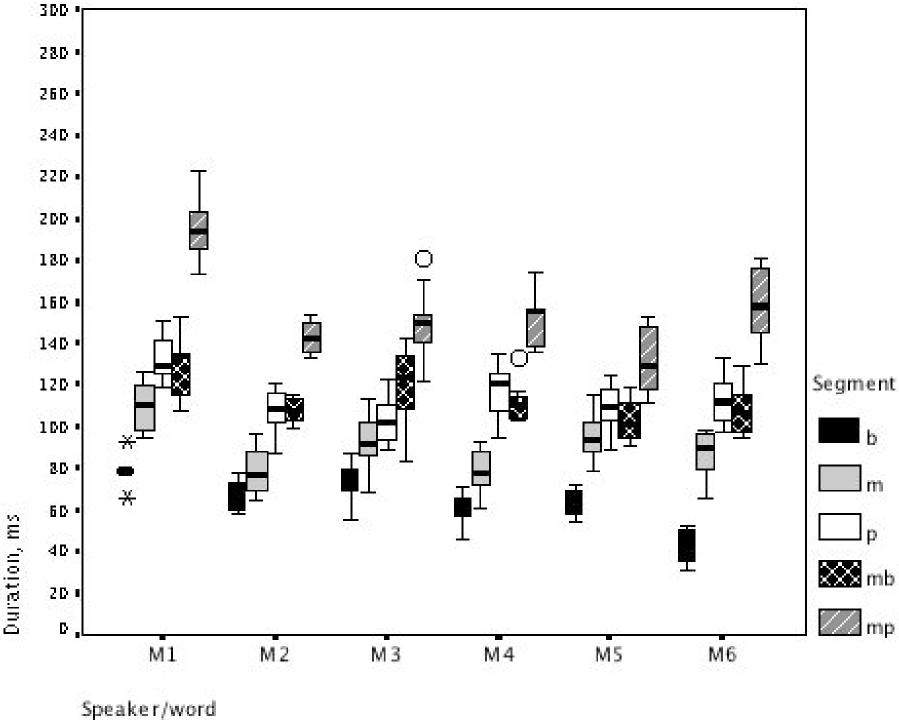

Figure 5.19: Manado Malay. Duration of bilabials in medial position for ten repetitions (except: M1 /mp/–6; M2 /m/–9; M3 /b/–9; M4 /b/–9, /m/–8; M5 /b/–8, /m/–8; M6 /t/–9). Difference between /m/ and /mb/ significant at p≤.001 for M3, M4, M5, M6; p≤.01 for M1.

For all six speakers, /b/ is the shortest segment, followed, more or less closely depending on the speaker, by /m/. The /mp/ sequence is the longest target sound for all speakers. /p/ and /mb/ fall somewhere in between, with their durations being relatively comparable for most of the speakers. Regarding the relationship between the plain nasal and voiced NC, in this case /m/ and /mb/, Manado Malay speakers show some variation. For all of the speakers except M5, the difference between /m/ and /mb/ is highly statistically significant; nevertheless, although speakers M2 and M4 exhibit a large duration difference between the two groups with no overlap, for the other three speakers there is considerable overlap. For speaker M5, the duration of /m/ and /mb/ are comparable. The /mp/ sequence is significantly longer than its component parts—plain /m/ or /p/—for all speakers.

Durations of the component parts of the bilabial NCs and their corresponding plain segments are presented in the following bar graph.

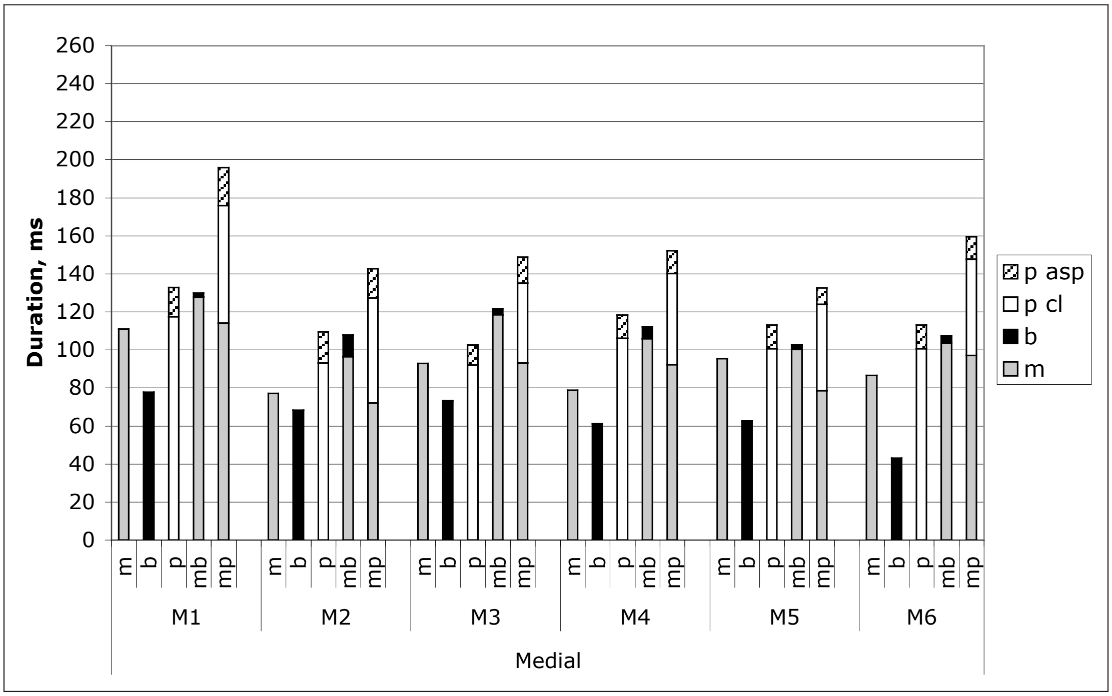

Figure 5.20: Manado Malay. Average durations of component parts of bilabials in medial position, based upon data in figure 5.18.

The above bar graph reveals that the relative durations of component parts in the bilabial NC set in Manado Malay are very similar to those of the alveolars. In brief, /mb/ consists primarily of a nasal closure followed by a very short oral release, an average range across speakers of 2-11 ms, while /mp/ consists of a substantial nasal closure followed by a smaller oral component (smaller as compared to a plain /p/). Since the duration differences between plain nasals and NC clusters at the bilabial place are not as great as at the alveolar place, the nasal closures of the clusters are not as substantially longer in this case. Also as seen in the alveolars, the degree of aspiration in a plain /p/ versus /mp/ is comparable, despite a difference in the duration of the oral closure. The average duration of aspiration ranges across speakers from 9-20 ms.

5.3.3 Manado Malay- Velars

Minimal sets for the velar NC sequences were collected for all Manado Malay speakers. However, data from only two speakers are presented here. The boundary between the nasal and preceding vowel was extremely difficult to segment in most cases, as discussed in chapter 3, section 3.2.5, and therefore data from most of the speakers were considered unreliable and are not included. Data from two speakers—M3 and M4—were easier to segment and are therefore included; nevertheless, any questionable tokens were excluded, reducing the number of repetitions included in the calculations. For these reasons, the velar data should be interpreted as preliminary.

The languages in this study with clear unary NC sequences—Tamambo and Erromangan—do not have velar NC sequences for comparison with Manado Malay. The Manado Malay velars are nonetheless included in this study in an attempt to further inform the general character of NC clusters across places of articulation, given the differing results for alveolars and bilabials. The minimal set for velars is included in table 5.11 below. Duration data follow in figure 5.21.

Table 5.11: Target words for velars in medial position in Manado Malay

Target sound	Token	Gloss
/g/	/pa**g**i/	*n*, morning
/ŋ/	/pa**ŋ**i	*n*, t.o. vegetable dish
/k/	/pa**k**e/	*v*, to use
/ŋg/	/pa**ŋg**e/	*v*, to call out
/ŋk/	/pa**ŋk**o/	*v*, to hold on lap

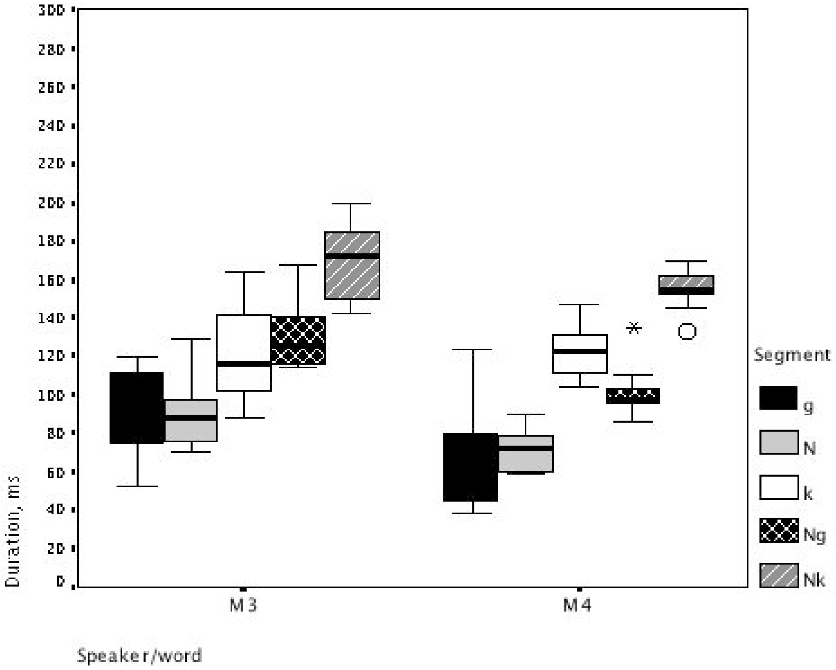

Figure 5.21: Manado Malay. Duration of velars in medial position for ten repetitions (except: M3 /ŋg/–6, /ŋk/–8; M5 /ŋ/–8, /ŋg/–7, /ŋk/–9). Difference between /ŋ/ and /ŋg/ significant at p≤.001 for both speakers.

For both speakers, /g/ and /ŋ/ are the shortest segments, while /ŋk/ is the longest. Regarding the relationship between /ŋ/ and /ŋg/, the cluster is significantly longer than the plain nasal for both speakers, consistent with the hypothesis that the NC clusters are longer than simple segments. The magnitude of this difference is less than it is for the alveolars, but greater than for the bilabials. /ŋk/ is also substantially longer than either of its component parts occurring independently.

The average durations of the component parts of the NC sequences and their corresponding plain segments are displayed in the following bar graph.

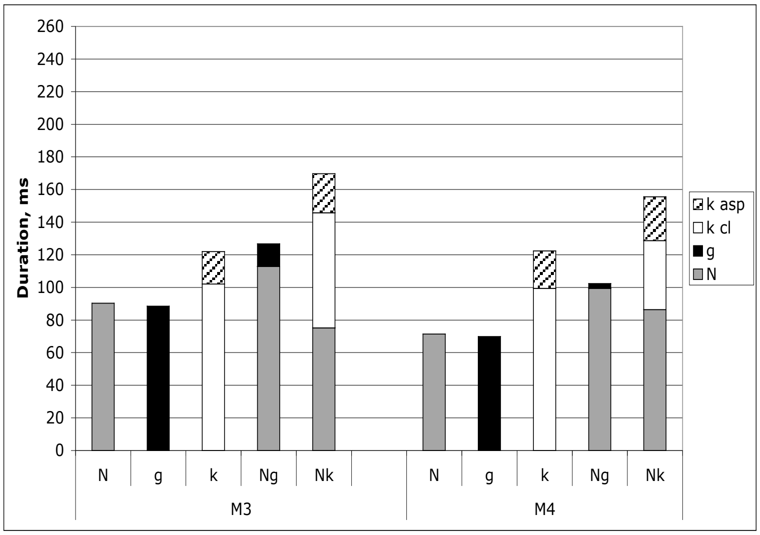

Figure 5.22: Manado Malay. Average durations of component parts of velars in medial position, based upon data in figure 5.20. [Note: "N" represents /ŋ/.]

The bar graph of velar data above has many similarities with those of the alveolars and bilabials. In brief, the majority of the /ŋg/ duration consists of a nasal closure, with only a short oral release, an average range of 3-14 ms. For /ŋk/, the degree of nasal closure varies between the two speakers (being on average shorter than a plain /ŋ/ for M3 and slightly longer for M4), while the oral phase of the sequence is shorter than that found in a plain /k/. Aspiration remains fairly stable (although it is longer in the velars than at the other places of articulation), an average range of 20-27 ms, regardless of whether the /k/ occurs independently or as a member of a cluster.

5.3.4 Manado Malay- Affricates

The minimal set for the NC voiceless alveopalatal affricate cluster is in table 5.12 below. The nasal used in the comparison is alveolar, rather than alveopalatal, as no data on palatal nasals were collected for this set. This could have an affect on the duration relationship between the plain nasal and NC sequence, given that the palatals are typically longer. The corresponding voiced affricate data are not included given that considerable segmentation difficulties rendered the data unreliable. Duration data follow in figure 5.23.

Table 5.12: Target words for affricates in medial position in Manado Malay

Target sound	Token	Gloss
/n/	/ku**n**o/	*a*, traditional
/tʃ/	/ku**tʃ**a/	*v*, to scrub
/ntʃ/	/ku**ntʃ**i/	*n*, key

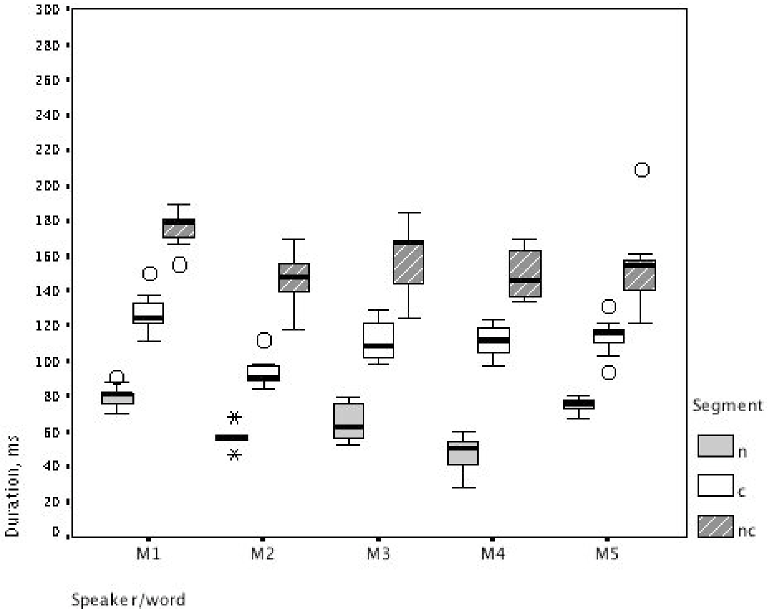

Figure 5.23: Manado Malay. Duration of alveopalatal affricates and alveolar nasals in medial position for ten repetitions (except: M2 /n/–8; M3 /ntʃ/–9; M5 /n/–9). Difference between /n/ and /ntʃ/ significant at p≤.001 for all speakers. [Note: “nc” represents /ntʃ/.]

For all five speakers, /n/ is the shortest segment, /ntʃ/ is the longest, and /tʃ/ falls between the two. Regarding the relationship between the plain nasal and the NC sequence, the /ntʃ/ is considerably longer than /n/ for all speakers, consistent with the hypothesis that the clusters are longer than unary segments. Some of this difference, however, is likely due to the voiceless character of the obstruent portion and the period of frication, to be discussed in more detail later, as well as the differing places of articulation.

The following figure contains a bar graph of the average durations of the component parts of /ntʃ/ and the corresponding plain alveolar segments.

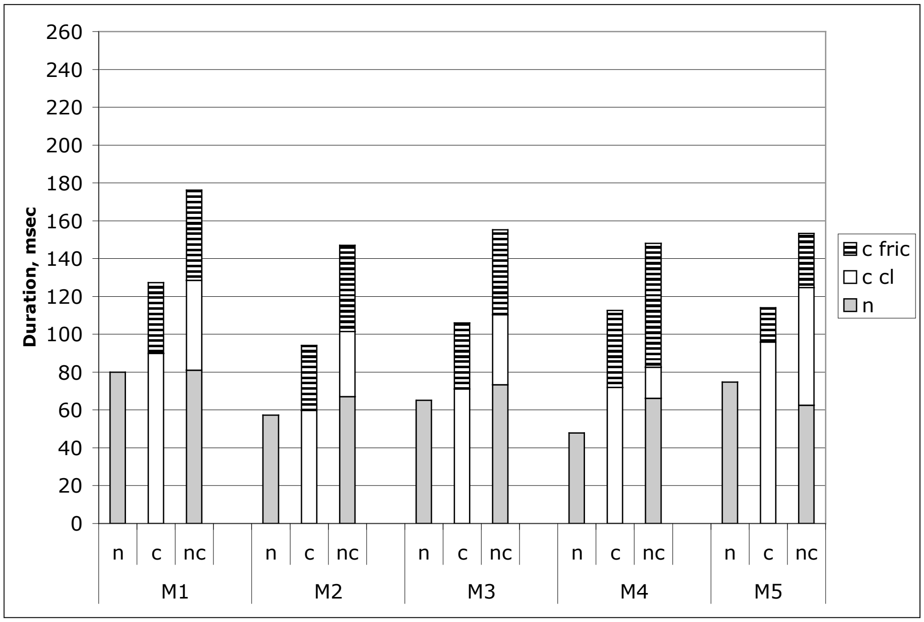

Figure 5.24: Manado Malay. Average durations of component parts of alveopalatal affricates and alveolar nasal in medial position, based upon data in figure 5.23. [Note: “nc” represents /ntʃ/.]

As the bar graph reveals, the average duration of the nasal portion of /ntʃ/ is similar to that of a plain alveolar nasal. The oral phase of the sequence is shorter than that found in a plain /tʃ/ (although not as substantially shorter as compared to the difference between plain voiceless stops and NC̥ at other places of articulation). The degree of frication varies depending upon the speaker. For example, M5 has a relatively small fricated portion in both the plain affricate and the NC cluster, similar to the aspirated component of voiceless stops seen previously, while M4 has relatively long aspirated portions when compared to the duration of the oral closure. The amount of frication remains relatively stable across the plain and cluster environments, and although it varies somewhat, it notably does not vary in accordance with the total duration of the oral phase. For example, M4's /tʃ/ exhibits a longer closure portion than fricated portion, while this speaker's /ntʃ/ exhibits a considerably longer fricated portion. The component parts of /tʃ/ appear to be less uniform in duration across speakers than those observed in the voiceless stops seen earlier in the section. Figure 5.25 below illustrates the variation in /ntʃ/ realization with representative tokens of /ku**ntʃ**i/ by M5 (a) and M4 (b).

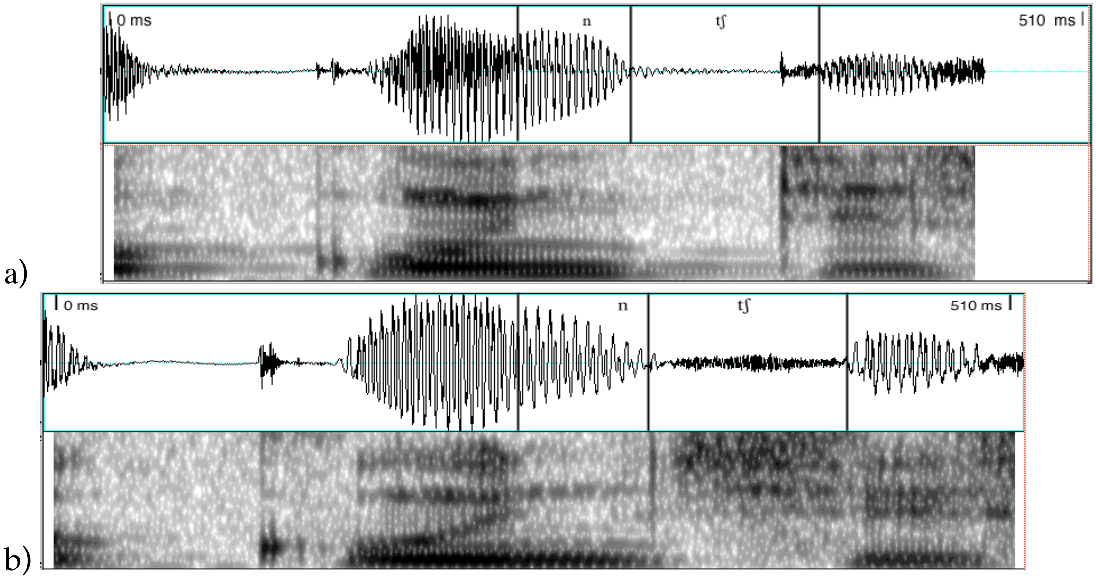

Figure 5.25: Manado Malay. Representative waveforms and spectrograms of /kuntʃi/ by M5 (a) and M4 (b). Window length is 510 ms each. Frequency on the Y-axis is 0-5000 Hz.

As seen above, M5’s NC cluster (a) consists of a nasal closure (58 ms), oral closure (78 ms), and oral release (21 ms), while M4’s cluster (b) consists of a nasal closure (71 ms) followed by a fricated oral release (99 ms), with no oral closure. These speaker tendencies hold fairly steadily across repetitions. The voiced NC affricates, which are not included here due to labeling difficulties, appear to be less likely to have an oral closure, and to have shorter periods of frication.

5.3.5 Manado Malay summary

In Manado Malay, the NC sequences form clusters, and therefore the hypothesis is that the sequences will have greater duration than a plain nasal or stop. As illustrated by the English data in section 5.1.1 and discussed in chapter 3, section 3.1.1, however, the expectation is not necessarily that the cluster will be equal in duration to the sum of the parts (when they occur independently). This point is reinforced by an additional set of Manado Malay data included in appendix C, figure C.2, which compares the duration of the cluster /ks/ to that of a plain /k/, and reveals greater duration of the cluster, but a reduction in duration of /k/ when it occurs in the cluster, as compared to its occurrence intervocalically.

In the case of the alveolars, the data presented above reveal that the duration of an NC cluster is significantly longer than that of a plain nasal, for all of the speakers. The average ratio of n:nd, as displayed in table 5.13 below, is 1:1.7. This pattern, whereby the clusters are longer than the single segments, is less pronounced but still significant at the velar place of articulation, and present for most, though not all, speakers at the bilabial place of articulation. In brief, the NC clusters in Manado Malay can be generally characterized as being longer than a single segment, with some explanation necessary to account for why not all speakers show this tendency as strongly with the bilabials. In the case of the affricates, the sequence is again considerably longer than the plain nasal. Some of this difference, however, must be attributed to the fact that the oral portion is fricated and voiceless (not simply because the NC forms two segments rather than one); the importance of the degree of this difference, in comparison with the other languages in the study, will be discussed later.

Table 5.13: Manado Malay. N:NC ratios, N:NC; N=1, NC=X

NC clusters	**Alveolar (Medial)**		**Bilabial (Medial)**		**Velar (Medial)**		**Affricate (Medial)**
	NC̬	NC̥	NC̬	NC̥	NC̬	NC̥	NC̥
M1	1.6	2.1	1.2	1.8	---	---	2.2
M2	1.9	2.4	1.4	1.9	---	---	2.6
M3	1.6	2.2	1.3	1.6	1.4	1.9	3.1
M4	1.5	2.2	1.4	1.9	1.4	2.2	2.4
M5	1.6	2	1.1	1.4	---	---	2
M6	1.7	2.8	1.2	1.8	---	---	---
Average	**1.7**	**2.3**	**1.3**	**1.7**	**1.4**	**2**	**2.5**

5.4 Pamona

As illustrated in chapter 2, section 2.2.3, Pamona has tautosyllabic NC clusters. The sequences occur with both voiced and voiceless obstruents, in contrast to plain voiced and voiceless obstruents, and they occur both word-initially and word-medially. At each place of articulation under consideration, therefore, there are both voiced and voiceless plain stops, plain nasals, and NC̬ and NC̥ sequences, as illustrated for the alveolar place of articulation in the following figure.

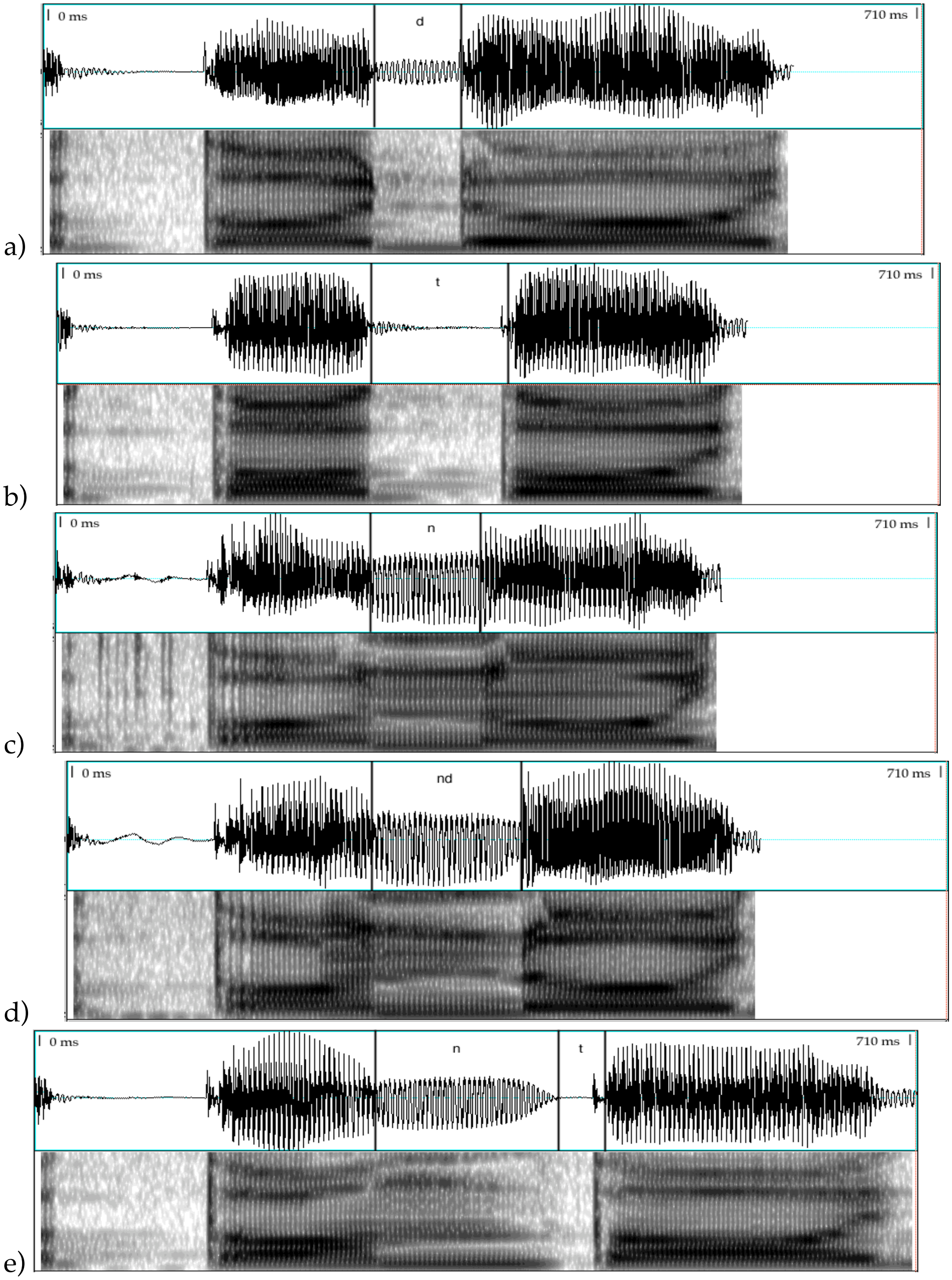

Figure 5.26: Pamona. Representative waveforms and spectrograms of /todo/ ‘to knock head’ (a), /toto/ ‘pair’ (b), /tono/ ‘at ease’ (c), /tondo/ ‘next to’ (d), and /tonto/ ‘to empty out’ (e) by P3. Window length is 710 ms each. Frequency on Y-axis is 0-5000 Hz.

Figure 5.26 contains representative spectrograms of the single segments and NC clusters in word medial position at the alveolar place of articulation, by P3: the /d/ from /to**d**o/ 'to knock head', /n/ from /to**n**o/ 'at ease', /t/ from /to**t**o/ 'pair', /nd/ from /to**nd**o/ 'next to', and /nt/ from /to**nt**o/ 'to empty out'.

As illustrated above, /d/ tends to be the shortest segment, followed closely by /n/ (67 and 88 ms, respectively, above). /t/ is generally longer than the other simple segments, here 118 ms, and includes a very brief period of aspiration (6 ms). Similar in length to /t/ is the voiced NC cluster /nd/, which consists of a long nasal closure followed by an oral release, here a total of 120 ms. Finally, the NC̥ cluster /nt/ is substantially longer than the simple segments or the voiced cluster, here 186 ms, and consists of a long nasal closure (151 ms), followed by an oral closure (25 ms) and brief period of aspiration (10 ms).

Given that Pamona has both NC̬ and NC̥ sequences at each place of articulation under investigation, and in both initial and medial word position, there is a larger amount of data for this language than the others in this study. Box plots containing duration data for NC̬ and NC̥ sequences and corresponding plain nasals and stops, initially and medially, are presented for the alveolars, bilabials, velars, and alveopalatal affricates. Voiced affricate data are not included, however, since—as with Manado Malay—considerable labeling difficulties make the data unreliable.

In most cases, separate NC̬ and NC̥ sets were collected to ensure the best correspondence between the particular NC and the plain nasal and stop. For example, the voiced velar set in medial position is /daŋga, daŋa, dago/, while the voiceless is /beŋka, beŋa, beka/. The different sets are combined in some of the box plots, however, in order to allow for comparison across all of the segment and sequence-types. In these cases, the plain nasal data from the voiced set are selected for display (i.e. the data from /da**ŋ**a/ but not /be**ŋ**a/). However, the plain nasals from the two sets never differ significantly in duration, as supported by box plots in appendix D comparing the durations of the nasals. These plots indicate that the use of nasal data from just one set is reliable for comparative purposes, and further that the differing segments preceding and following the target sounds in the each sets do not affect the durations of the target sounds.

In chapter 2, section 2.2.3, I argued that the NC sequences in Pamona are tautosyllabic but that they form clusters. In this section, the data reveal that the durations of the sequences in Pamona pattern more like the heterosyllabic clusters in Manado Malay than the tautosyllabic unary segments in Tamambo. In brief, Pamona NC sequences have a strong tendency to be significantly longer than plain nasals and stops. Given that Pamona has NC sequences in initial position whereas Manado Malay does not, this language offers additional interesting data for comparison with the initial unary NC sequences in Tamambo.

5.4.1 Pamona- Alveolars

Table 5.14 contains the target words for the alveolars in initial position in Pamona. Two separate sets were collected for the NC̬ and NC̥ sequences, in order to provide the best match with corresponding plain segments within each set. For comparative purposes, the sets are combined in the following box plot. The duration data for plain /n/ come from the word in the voiced set (/**n**eka/) rather than the voiceless set (/**n**ana/). However, as seen in appendix D, figure D.1, the duration values of the /n/'s from the different sets do not differ significantly. In calculating ratios for later discussion, however, only the duration data for the /n/ from the matching set are included. Duration data follow the table in figure 5.27.

Table 5.14: Target words for alveolars in initial position in Pamona

Target sound	Token	Gloss
NC̬ set		
/n/	/**n**eka/	*n, proper name*
/d/	/**d**eki/	*n, proper name*
/nd/	/**nd**eki/	*v*, to climb
NC̥ set		
/t/	/**t**ana/	*n*, earth
/nt/	/**nt**ani/	*n*, another
Corresponding /n/ for NC̥ set- see appendix D, figure D.1		
/n/	/**n**ana/	*n*, wound

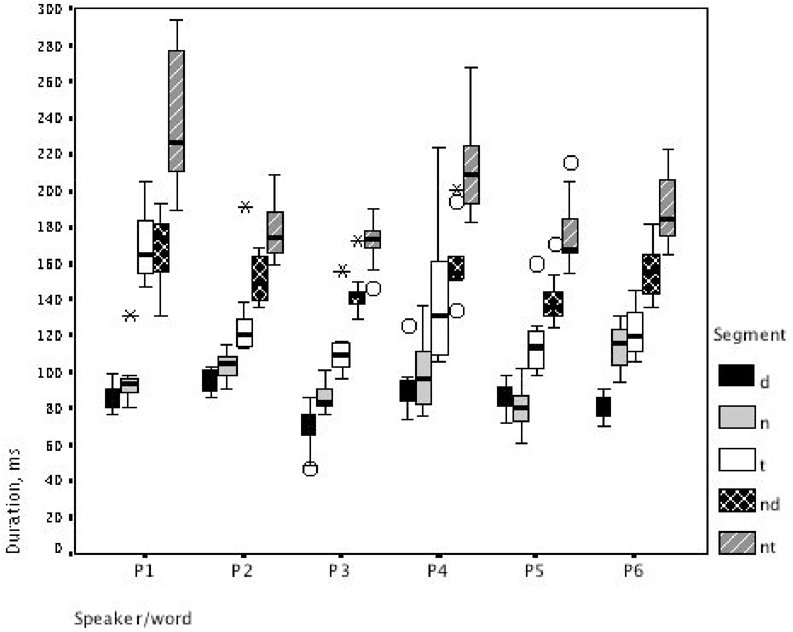

Figure 5.27: Pamona. Duration of alveolars in initial position for ten repetitions (except: P1 /n/–9, /nd/–9, /nt/–7; P2 /nt/–9; P4 /nd/–9; P5 /t/–9 /nd/–9; P6 /n/–9). Difference between /n/ and /nd/ significant at p≤.001 for all speakers.

As seen above, /d/ and /n/ are the shortest sounds for all of the speakers, the two being very similar in duration, with the exception of P6, who exhibits a systematic duration difference between the segments, /n/ being substantially longer. /nt/ is by far the longest sound for all of the speakers, and /t/ and /nd/ fall between the extremes, /t/ being the shorter of the two. (Recall that aspiration is included in the total duration measurements for voiceless stops.) Regarding the relationship between /n/ and /nd/, the sequence is substantially longer than the plain nasal for all of the speakers. Not only is this difference highly significant, but it involves no overlap between the groups for any of the speakers, supporting the hypothesis that clusters are longer than single segments. Finally, /nt/ is also substantially longer than /n/ and /t/ for all of the speakers.

Table 5.15 contains the target words for the alveolar set in medial position. The complete set was recorded for three of the speakers, while only the voiced set was recorded for the other three speakers (P1, P4, P5); therefore there are gaps in the data for this latter group in the following box plot. However, a separate NC̥ set was recorded for all of the speakers, and the results can be found in appendix D, figure D.2. (When later presenting the N:NC ratios, the n:nt ratios from the latter group of speakers will come from this additional set). Duration data for the target sounds follow in figure 5.28.

Table 5.15: Target words for alveolars in medial position in Pamona

Target sound	Token	Gloss
/n/	/to**n**o/	*v*, to knock head
/d/	/to**d**o/	*a*, at ease
/t/	/to**t**o/	*n*, pair, counterpart
/nd/	/to**nd**o/	*p*, next to
/nt/	/to**nt**o/	*v*, to empty out

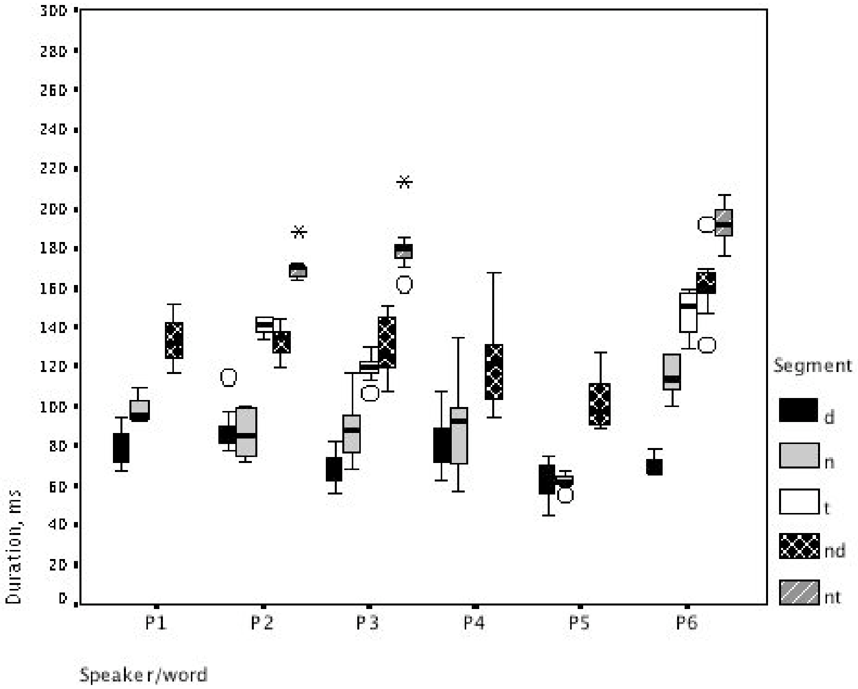

Figure 5.28: Pamona. Duration of alveolars in medial position for ten repetitions (except: P3 /nt/–9; P5 /n/–7; P6 /nt/–9). Difference between /n/ and /nd/ significant at p≤.001 for all speakers.

As seen above, /d/ and /n/ are the shortest sounds for all of the speakers, as they were in initial position as well. Further, the patterns in medial position are remarkably similar to those in initial position for these segments; for example, P4 exhibits no duration difference between the two groups in either position, while P6 exhibits a substantially longer /n/ than /d/ in both positions. /nt/ is the longest sound for all of the speakers. /nd/ and /t/ fall in between these other sounds in terms of duration. However, unlike in initial position, where /nd/ was longer than /t/, in medial position the two sounds show more variation in their relationship depending upon the speaker. Regarding the relationship between /n/ and /nd/, /nd/ is highly significantly longer than /n/ for all of the speakers, with no overlap in duration between the two groups for any of the speakers. /nt/ is also obviously much longer than plain /n/ and /t/ for all of the speakers. Given that the Pamona sequences are argued to form clusters, these data are in agreement with the hypothesis that clusters are longer than single segments. The fact that the medial data pattern so closely with the initial data suggests that the status of the NC does not differ between the two word positions, being unary initially (where a non-syllabic nasal has no option of heterosyllabifying) and a cluster medially. The n:nd ratio is quite similar between the two word positions (as is shown in table 5.22 at the end of the section). In general, all sounds in medial position tend to be slightly shorter than in initial position.

The following bar graph contains information on the relative durations of the component parts of the NCs. Due to the large amount of data in Pamona (number of contrasts, word positions, and speakers) and difficulty in visually inspecting the graphs when all of the data are provided, combined with the fact that the same general patterns are observed across the speakers, the data from only two speakers are presented here. These speakers were chosen because they are representative, and because the full range of data is available for them. A graph containing data from all of the speakers can be found in appendix D, figure D.3.

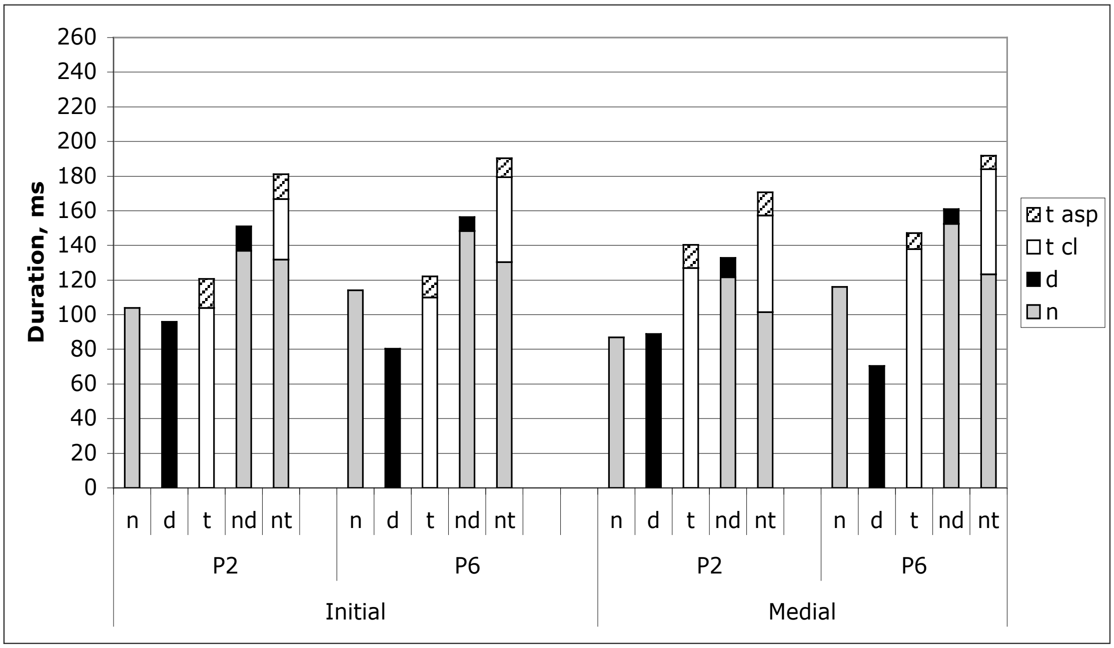

Figure 5.29: Pamona. Average durations of component parts of alveolars in initial and medial position by speakers P2 and P6, based upon data in figures 5.27 and 5.28.

As seen above, the majority of the duration in an /nd/ sequence is comprised of a nasal closure, with only a short oral portion, observed in both initial and medial position, an average range across all of the speakers of 8-25 ms. Since the total duration of this cluster is longer than plain /n/, the result is that the nasal closure itself is longer in the cluster than the simple /n/. For /nt/, the nasal closure is longer than, or as long as, the nasal closure of a plain nasal, while the oral portion is substantially shorter than that seen in a plain /t/. The amount of aspiration in /t/ remains fairly steady regardless of whether it is part of a plain /t/ or the shortened oral phase of an /nt/ sequence, an average range across speakers of 8-17 ms.

5.4.2 Pamona- Bilabials

This section contains the duration data for bilabials in Pamona. The minimal set for the bilabial data in initial position is in table 5.16 below. In this case, only voiced data are available, because there are no words with initial /mp/ (which may represent a gap in the phonotactics, or may indicate that the sequence is extremely rare in this position and therefore did not surface during any elicitation sessions). Duration data follow in figure 5.30.

Table 5.16: Target words for bilabials in initial position in Pamona

Target sound	Token	Gloss
/m/	/**m**ambe/	*v*, to berate
/b/	/**b**amba/	*n*, wooden roof supports
/mb/	/**mb**amba/	*v*, to tell a lie

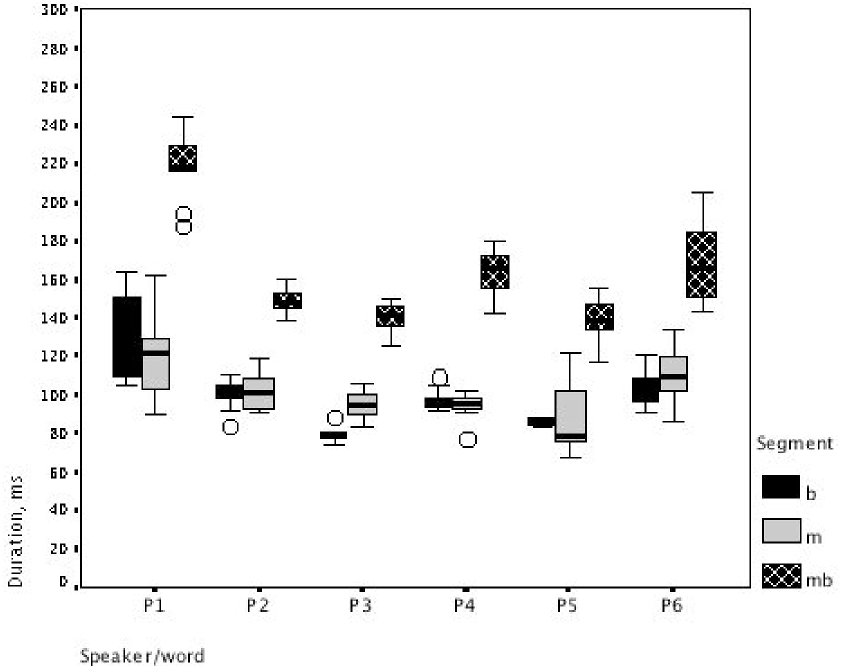

Figure 5.30: Pamona. Duration of bilabials in initial position for ten repetitions (except: P1 /b/–4, /mb/–9; P2 /m/–9; P3 /b/–6, /mb/–9; P4 /b/–9, /m/–9, /mb/–9; P5 /b/–2, P6 /b/–9). Difference between /m/ and /mb/ significant at p≤.001 for all speakers.

As seen above, /m/ and /b/ are the shortest segments for all of the speakers, the sounds being essentially the same length, with some difference in their relative relationship depending upon the speaker. /mb/ is by far the longest sound for all of the speakers. Regarding the relationship between /m/ and /mb/, the /mb/ is highly significantly longer than /m/ for all of the speakers, supporting the hypothesis that clusters are longer than unary segments. Importantly, the /m/ to /mb/ relationship in initial position in Pamona looks very different than it does in unary Tamambo, where /m/ and /mb/ are either the same, or of very similar, durations. This generalization holds even though the absolute durations of /m/ in the two languages are roughly the same across the speakers, therefore highlighting the greatly increased length of Pamona /mb/. The degree of difference in the N:NC relationship in Pamona bilabials in initial position is very similar to that seen for the alveolars in initial position.

The minimal sets for medial position are in table 5.17 below. Separate sets were collected for the NC̬ sequence (/to**mb**u, to**b**u, to**m**u/) and the NC̥ (/ta**mp**a, ta**p**a, ta**m**a/). The data are combined in the following box plot for ease of comparing the different sounds, the plain nasal data being from the voiced set. A comparison of the duration of the plain /m/ in /to**m**u/ and /ta**m**a/, as seen in appendix D, figure D.4, reveals no statistically significant difference between the durations of the two groups for any of the speakers, thus the use of just one of the sets in the plot poses no problem. The NC̬ set was particularly difficult to label for speakers P4 and P5, and therefore the data from these two speakers have been excluded, and their plain /m/ data in the box plot is from /ta**m**a/. Duration data follow the table in figure 5.31.

Table 5.17: Target words for bilabials in medial position in Pamona

Target sound	Token	Gloss
NÇ̬ set		
/m/	/to**m**u/	*v*, to meet
/b/	/to**b**u/	*v*, to gather
/mb/	/to**mb**u/	*v*, to draw water
NÇ̥ set		
/m/	/ta**m**a /	*n*, uncle
/p/	/ta**p**a	*v*, to cook with smoke
/mp/	/ta**mp**a/	*n*, place

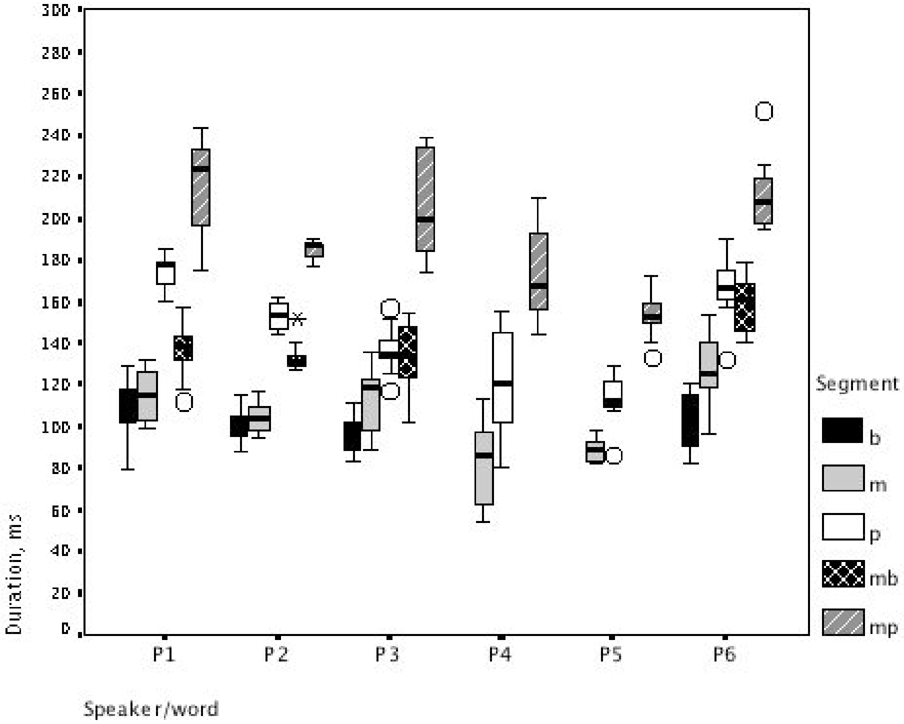

Figure 5.31: Pamona. Duration of bilabials in medial position for ten repetitions (except: P1 /mp/–9; P2 /m/–8, /b/–8; P6 /b/–8). Difference between /m/ and /mb/ significant at p≤.001 for P1, P2, P6; p≤.05 for P3.

As seen above, /b/ and /m/ are equally the shortest segments for all of the speakers, except for P6 who has a significantly longer nasal (parallel to this

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[2] /m/ duration data is from /to**m**u/ for speakers P1, P2, P3, and P6.

[3] /m/ duration data is from /ta**m**a/ only for speakers P4 and P5.

speaker's alveolars). /mp/ is by far the longest sound or sequence for all of the speakers. The duration of /mb/ and /p/ fall somewhere in between, with their relative relationship varying depending upon the speaker. Regarding the relationship between /m/ and /mb/, /mb/ is significantly longer than /m/ for the four speakers for whom there are data, in line with expectations that clusters are longer than unary segments. The degree of this difference is not as large as it is for the alveolars, however, with some speakers having the same degree of difference as those in the unary NC language Tamambo, raising the question of why this variation based upon place of articulation in medial position should exist.

The following bar graph contains data on the average duration of the component parts of the bilabials, with two representative speakers presented (and all speakers displayed in appendix D, figure D.5).

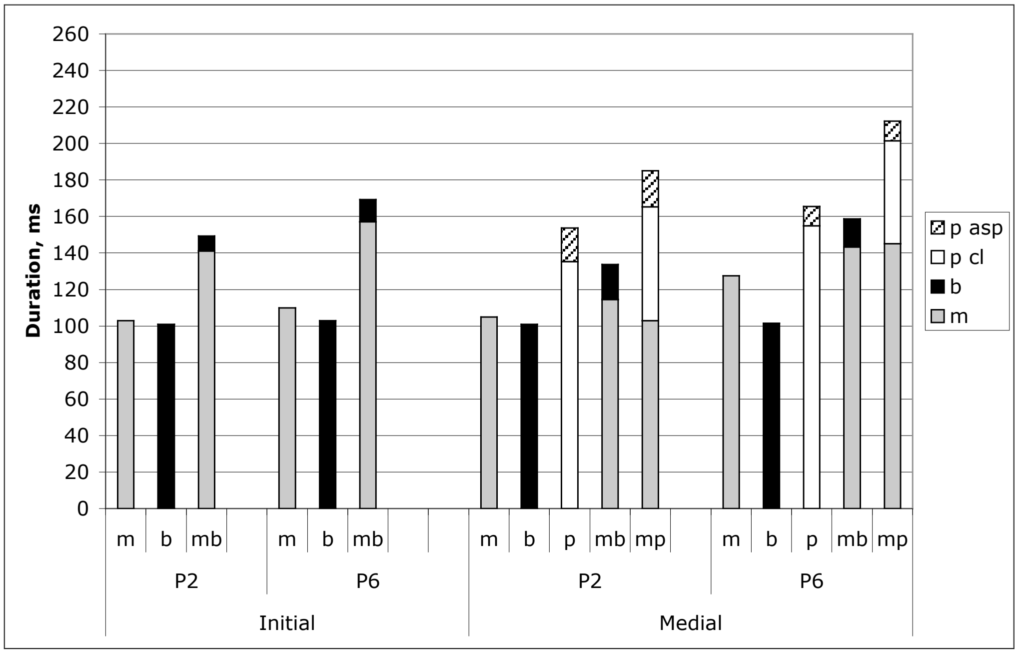

Figure 5.32: Pamona. Average durations of component parts of bilabials in initial and medial position by speakers P2 and P6, based upon data in figures 5.30 and 5.31.

As seen above, the majority of an /mb/ sequence is comprised of a nasal closure, with only a brief oral release, an average range across all of the speakers and word positions of 3-19 ms. Given that the total duration of the /mb/ in initial position is much longer than a simple /m/, the result is a much longer nasal closure in /mb/ than plain /m/. In medial position, however, where the difference between the duration of /m/ and /mb/ is not as large, the amount of nasal closure is only slightly longer in the /mb/ cases. For /mp/, the amount of nasal closure is about the same as that seen in a plain nasal, while the duration of the oral phase of the sequence is much shorter than that seen in a plain /p/. The average range of aspiration across speakers is 11-20 ms. In general, the relative durations of the component parts of the bilabials are similar to those of the alveolars.

5.4.3 Pamona- Velars

This section contains the duration data for velars in Pamona. As mentioned previously, the velar data were particularly challenging to label for speakers of all of the languages. Data from the three Pamona speakers whose waveforms and spectrograms could be most reliably labeled and measured are included, to give an idea of the pattern at this place of articulation. Given the small number of speakers, however, and the smaller number of repetitions (due to questionable tokens being excluded), the velar data should be regarded as preliminary.

In initial position, separate NÇ̬ and NÇ̥ sets were collected. The results are combined in the following box plot for ease of comparison. The data displayed for the plain /ŋ/ are those collected for the NÇ̬ set. However, a plot comparing the duration of plain /ŋ/ in each set (appendix D, figure D.6) reveals that the two groups do not differ significantly in duration for any of the speakers, and therefore the use of just the voiced set in the plots is reliable for the comparisons. Ratios used in later discussion will, however, use only the /ŋ/ data from the corresponding set. Table 5.18 contains the target words for velars in initial position. Duration data follow the table in figure 5.33.

Table 5.18: Target words for velars in initial position in Pamona

Target sound	Token	Gloss
NC̬ set		
/ŋ/	/**ŋ**aru/	*n,* t.o. traditional dance
/g/	/**g**alo/	*v,* to mix
/ŋg/	/**ŋg**aru/	*n,* cat
NC̥ set		
/k/	/**k**awo/	*n,* small field
/ŋk/	/**ŋk**ai/	*n,* grandfather
Corresponding /ŋ/ for NC̥ set- see appendix D, figure D.6.		
/ŋ/	/**ŋ**aju/	*n,* song

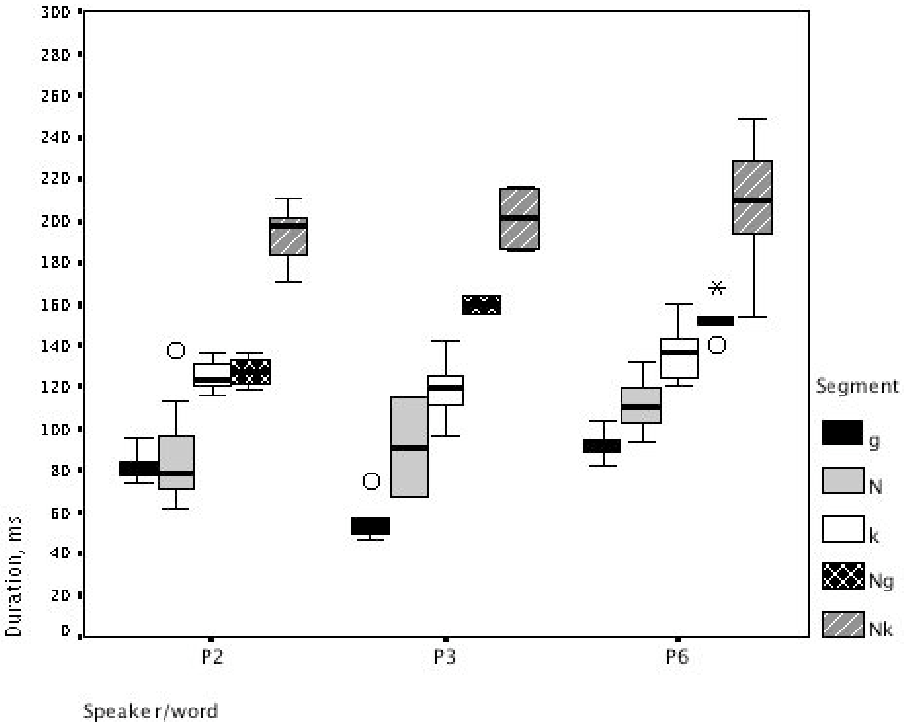

Figure 5.33: Pamona. Duration of velars in initial position for ten repetitions (except: P1 /ŋ/–8, /k/–9, /ŋɡ/–4; P2 /ɡ/ –5, /ŋ/–2, /k/ –8, /ŋɡ/–2, /ŋk/–4; P6 /ɡ/–9, /ŋ/–6, /k/–9, /ŋɡ/–6, /ŋk/–8). [Note: "N" represents /ŋ/.] (Statistical significance not calculated due to small number of tokens.)

As seen above, /ɡ/ is the shortest segment for two speakers, followed by /ŋ/, with the two being equally short for speaker P2. /ŋk/ is by far the longest sound for all of the speakers. The durations of /k/ and /ŋɡ/ fall in between, with /ŋɡ/ being longer for two speakers, and equally as long as /ŋ/ for P2. Regarding the relationship between /ŋ/ and /ŋɡ/, the cluster is substantially longer than the plain nasal for all of the speakers, supporting the hypothesis that clusters are longer than single segments. The difference between /ŋ/ and /ŋk/ is even more substantial, for all of the speakers.

Table 5.19 contains the target words for the velar data in medial position. As was the case in initial position, separate NC̬ and NC̥ sets were collected. The data are combined in the following box plot for ease of comparison, with the plain nasal data being from the target word in the voiced set. The duration of the plain nasal in each of the sets does not differ significantly, however, as seen in appendix D (figure D.7). Duration data follow in figure 5.32.

Table 5.19: Target words for velars in medial position in Pamona

Target sound	Token	Gloss
NC̬ set		
/ŋ/	/da**ŋ**a/	*n*, spider's web
/g/	/da**g**o/	*a*, good
/ŋg/	/da**ŋg**a/	*a*, incapable
NC̥ set		
/k/	/be**k**a/	*v*, to cleave open small objects
/ŋk/	/be**ŋk**a	*v*, to split
Corresponding /ŋ/ for NC̥ set- see appendix D, figure D.7.		
/ŋ/	/be**ŋ**a/	*v*, to open (container)

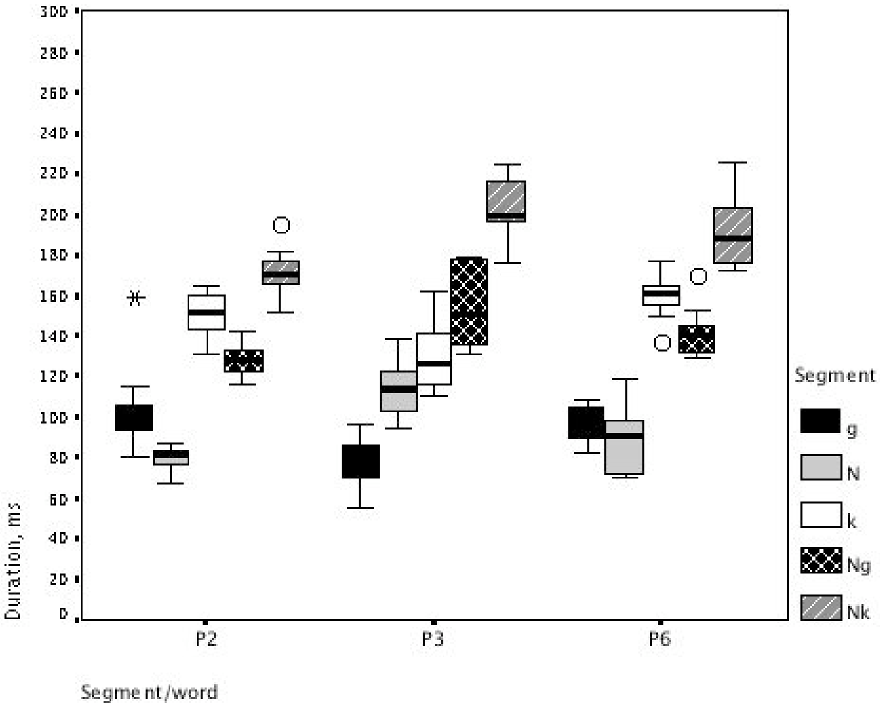

Figure 5.34: Pamona. Duration of velars in medial position for ten repetitions (except: P2 /ŋ/–9, /ŋg/–9; P3 /ŋ/–9, /ŋg/–6; P6 /ŋ/–5, /ŋg/–9). [Note: "N" represents /ŋ/.] (Statistical significance not calculated due to small number of tokens.)

As seen above, /g/ and /ŋ/ are the two shortest sounds for all of the speakers, with their relative relationship varying depending upon the speaker. /ŋk/ is by far the longest sound for all of the speakers. The durations of /k/ and /ŋg/ fall in between, with their relative durations varying depending upon the speaker. Regarding the relationship between /ŋ/ and /ŋg/, the cluster is substantially longer than the plain nasal for all of the speakers, supporting the hypothesis that clusters are longer than simple segments. /ŋk/ is also substantially longer than /ŋ/ for all of the speakers.

The following figure displays the average durations of the component parts of the velar NC sequences and corresponding plain segments for all three of the speakers.

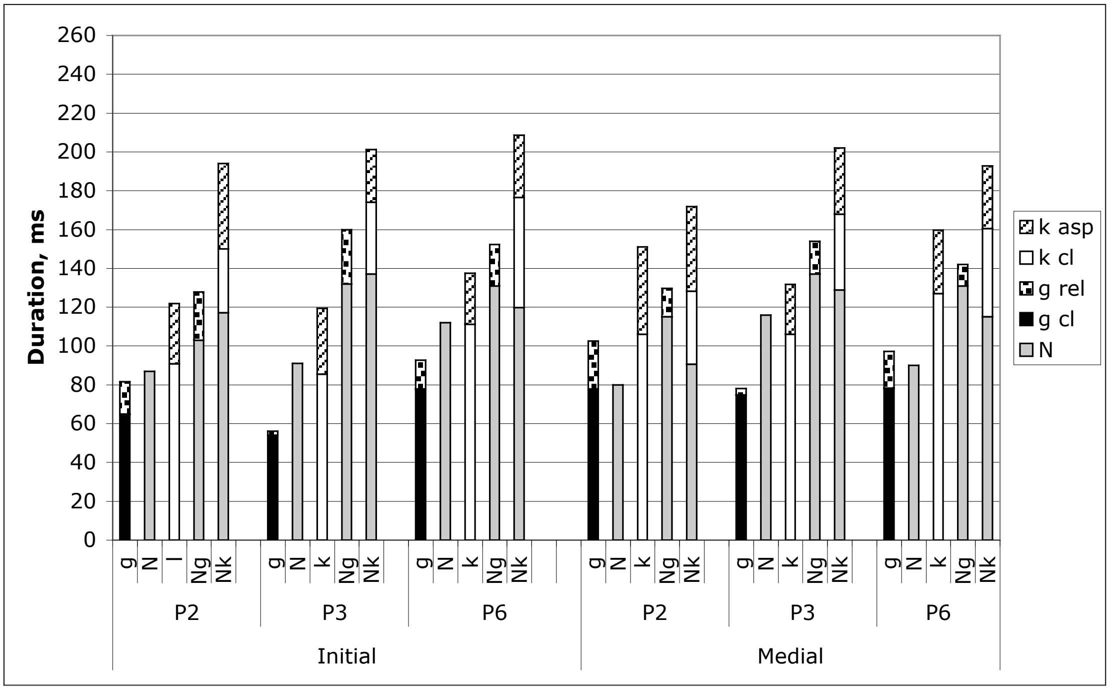

Figure 5.35: Pamona. Average durations of component parts of velars in initial and medial position, based upon data in figures 5.33 and 5.34. [Note: "N" represents /ŋ/.]

As seen above, the majority of the duration of an /ŋɡ/ sequence is comprised of a nasal closure, followed by a brief oral portion, an average range across speakers of 11-28 ms. The longer total duration of a sequence versus a plain nasal results in the nasal closure of the sequence being longer than a plain /ŋ/. /ŋk/ sequences are also largely composed of a nasal closure, one that exceeds the duration of that seen in a plain nasal. The oral phase of the sequence, however, is shorter than that of a plain stop. The durations of the component parts in the velar sequences are therefore similar to those observed at the other places of articulation. The velars do differ in one noticeable way from the other places, however, in that the proportion of the oral phase of a voiceless stop consisting of aspiration is greater, an average range across speakers of 26-45 ms. Like the other places of articulation, however, aspiration comprises a consistent amount of the oral phase whether the stop is simple or part of a sequence. The plain voiced stops also differ from those seen at other places (and contrast with the voiced velar stops in Manado Malay). Some Pamona speakers have a substantial release associated with /ɡ/, one that was not observed for bilabials or alveolars. In an /ŋɡ/ sequence, the release is present, but the oral closure portion is gone, having been replaced by a nasal closure.

5.4.4 Pamona- Affricates

This section contains the duration data for the NC alveopalatal affricates. As explained in chapter 2, section 2.2.3, the voiceless affricate always occurs with a preceding nasal in Pamona (arguably the phonetic realization of /ns/), with the exception of a few proper names. Pamona also has a voiced alveopalatal affricate, although duration data for this segment (and its NC counterpart) are not considered due to labeling difficulties and the resulting unreliability of the data. Table 5.20 contains the minimal set for initial position. As there are no words with a plain /tʃ/ in this position, the NC sequence will instead be compared with the plain alveolar fricative /s/ and stop /t/, as well as the nasal /n/. The mismatch in place and manner of articulation may affect the N:NC comparisons, as the palatal place, affricate manner, and voiceless laryngeal specifications all contribute to greater duration. The target words for /t/ and /n/ are the same as those used in the initial alveolar set in section 5.4.1. Duration data follow in figure 5.36.

Table 5.20: Target words for affricate in initial position in Pamona

Target sound	Token	Gloss
/n/	/**n**ana/	*v*, wound
/t/	/**t**ana/	*n*, earth
/s/	/**s**aŋo/	*v*, to catch fish
/ntʃ/	/**ntʃ**ani/	*v*, to know

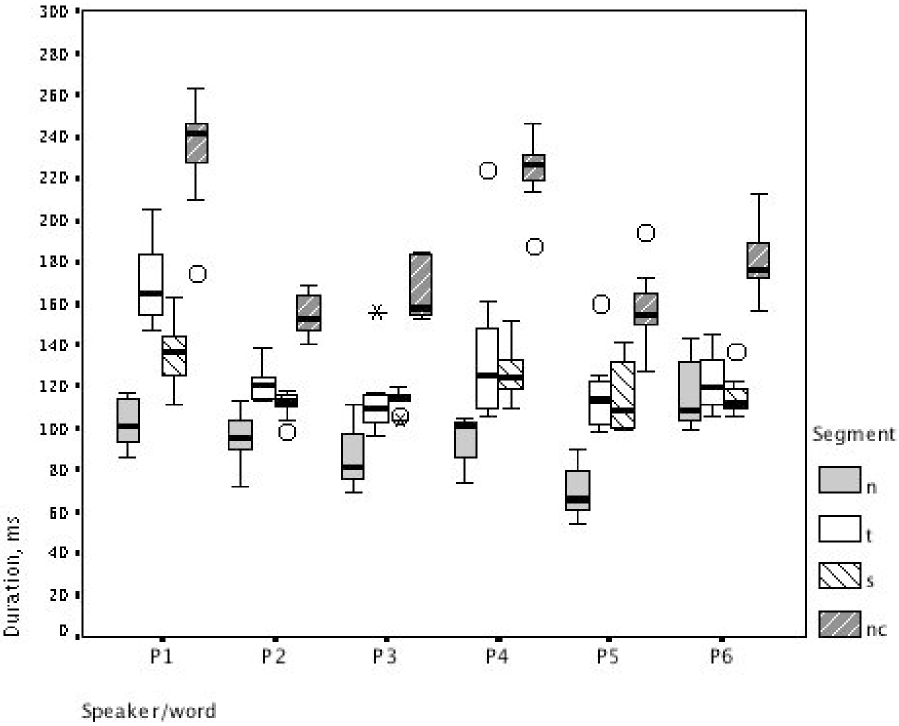

Figure 5.36: Pamona. Duration of NC alveopalatal affricate and alveolars in initial position for ten repetitions (except: P2 /ntʃ/–9; P3 /n/–9; P4 /n/–9, /t/–9, /s/–9, /ntʃ/–7; P5 /t/–9, /ntʃ/–9; P6 /ntʃ/–9). Difference between /n/ and /ntʃ/ significant at p≤.001 for all speakers. [Note: "c" represents /tʃ/.]

As seen above, /n/ is the shortest segment for five of the speakers and among the shortest for one speaker, P6, while /ntʃ/ is the longest. /t/ and /s/ fall between the two, being equivalent in duration for five of the speakers, and with P1 having a longer /t/. For P6, the three simple segments are all of equivalent duration. Regarding the relationship between /n/ and /ntʃ/, the cluster is substantially longer than /n/ for all of the speakers. Although the fact that the cluster is longer than the plain nasal is consistent with the hypothesis under consideration in this chapter, it is also the case that the sequence will have greater inherent length, as mentioned earlier. A fuller interpretation of this case will be considered in chapter 6, section 6.1.2.

Table 5.21 contains the target words for the affricates in medial position. In this case, a token with plain /tʃ/ is included in the comparison. (The word is a first name and likely borrowed from a neighboring language, but is commonly used in the Pamona-speaking region). Duration data follow in figure 5.37.

Table 5.21: Target words for affricates in medial position in Pamona

Target sound	Token	Gloss
/n/	/a**n**a/	*proper name*-female
/tʃ/	/a**tʃ**e/	*proper name*-male
/ntʃ/	/a**ntʃ**a/	*n*, t.o. mango

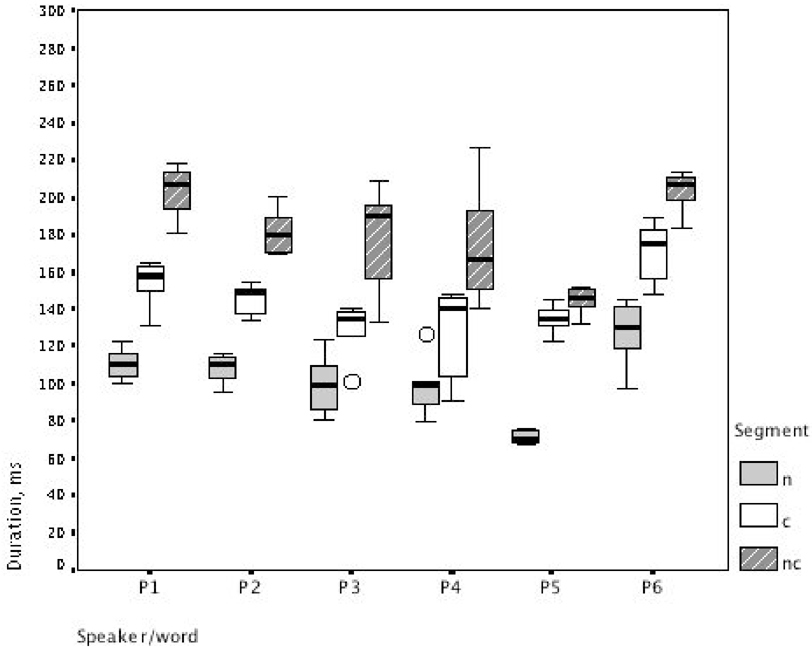

Figure 5.37: Pamona. Duration of alveopalatal affricates and alveolar nasals in medial position for ten repetitions (except: P1 /ntʃ/–8; P4 /n/–7, /t/–9, /ntʃ/–6). Difference between /n/ and /ntʃ/ significant at p≤.001 for all speakers. [Note: "c" represents /tʃ/.]

As seen in figure 5.37, /n/ is the shortest segment for all of the speakers while /ntʃ/ is the longest. The duration of /tʃ/ falls between the two for all of the speakers, although for P5, the duration of /tʃ/ is quite close to that of /ntʃ/. Regarding the relationship between /n/ and /ntʃ/, the cluster is substantially longer than the plain nasal for all of the speakers. As mentioned above, although the longer cluster is consistent with the hypothesis being explored here, the results will have to be interpreted in light of the fact that some of the cluster's length must be attributed to it being voiceless and an affricate.

The following bar graph displays the average durations of the component parts of the sounds for two representative speakers (data for all speakers are in appendix D, figure D.8).

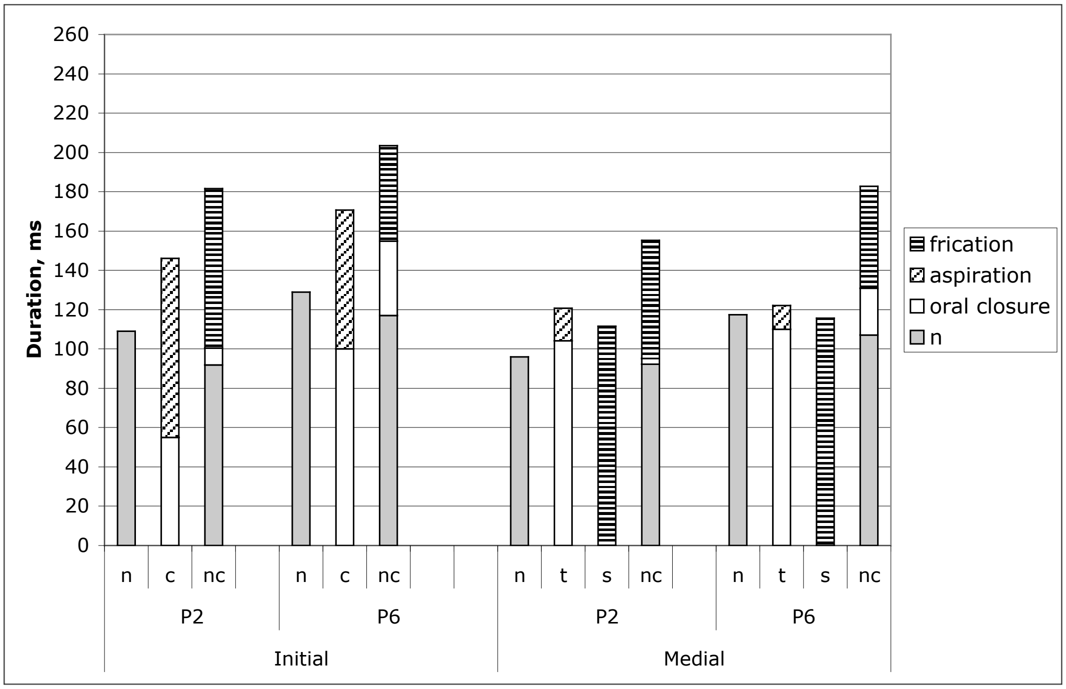

Figure 5.38: Pamona. Average durations of component parts of alveopalatal affricates and alveolar nasals in initial and medial position by speakers P2 and P6, based upon data in figures 5.36 and 5.37. [Note: "c" represents /tʃ/.]

As seen above, over half of the total duration of /ntʃ/ is comprised of a nasal closure, of similar duration to that in a plain /n/. Regarding the oral phase, the amount of duration consisting of a closure versus fricated release varies depending upon the speaker and word position. P2, for example, has a small oral closure for /ntʃ/ in initial position and virtually no oral closure in medial position. P6 has a longer oral closure in both positions, and in initial position the closure comprises half of the duration of the oral phase. In general, there is much more inter-speaker variation observed with the affricates than there is with the plain stops. Further, the release phase of the affricates (frication) is much longer than the release phase of the plain stops (aspiration). Figure 5.39 below illustrates the variation in realization of /ntʃ/, with representative tokens of /antʃa/ by P4 (a) and P2 (b).

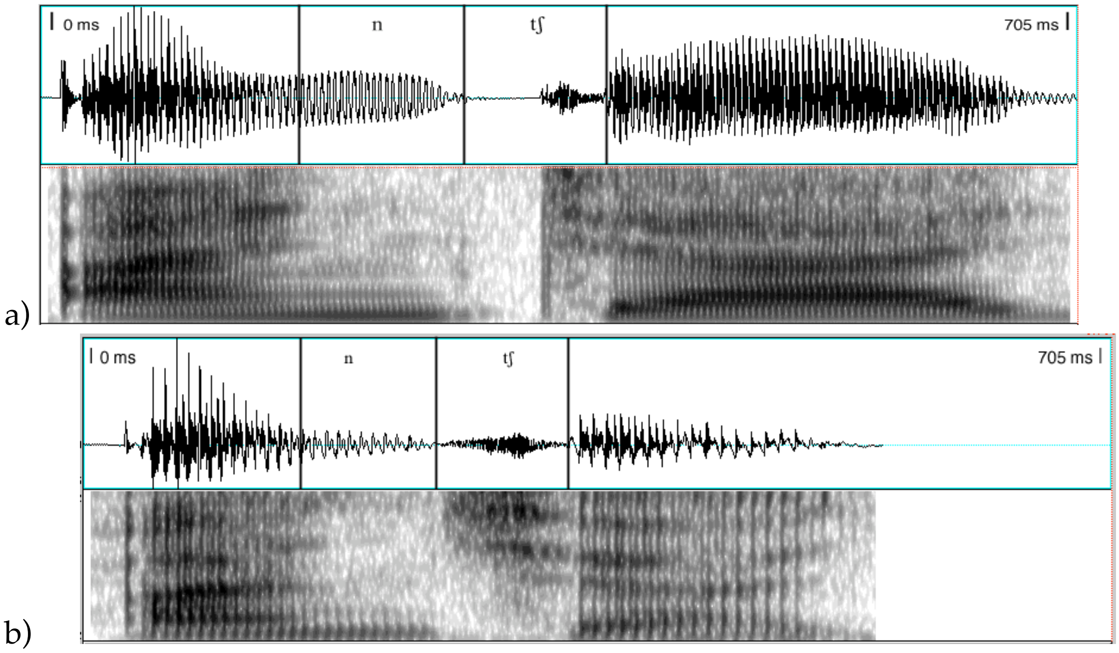

Figure 5.39: Pamona. Representative waveforms and spectrograms of /antʃa/ by P4 (a) and P2 (b). Window length is 705 ms. Frequency on the Y-axis is 0-5000 Hz.

As seen above, P4's /ntʃ/ sequence (a) consists of a nasal closure (107 ms), followed by an oral closure (63 ms), followed by a fricated release (42 ms). P2's sequence consists of a nasal closure (99 ms) and an oral fricated release (92 ms), but lacks an oral closure. The difference in rate of speech observed between the speakers does not correlate with whether or not the affricates have an oral closure. Regarding the voiced NC affricates, which are not included here due to labeling difficulties, they appear to be even less likely to have an oral closure, and to have much shorter periods of frication.

5.4.5 Pamona summary

The general claim under investigation in this study is that NC clusters and unary NC segments differ phonetically, specifically in that the clusters have a longer duration. In chapter 2, section 2.2.3, I argued that the NC sequences in Pamona, while tautosyllabic, form clusters. Looking just at the voiced NC sequences, the data reviewed in this section strongly support the above claim, in that NC̬ sequences in Pamona are substantially longer than plain nasals in four out of five cases considered (alveolars—initial and medial, bilabials—initial, velars—medial), and longer, although less significantly, for the fifth case (bilabials—medial). In all of the NC̥ cases, the cluster is also significantly longer than a plain nasal, a difference that must be attributed in part to the voicelessness of the obstruent portion of the sequence. Ratios comparing the plain nasals to the corresponding NC sequences at each place of articulation are in table 5.22 below. These ratios will be used in later discussions where the languages are compared with one another.

Table 5.22: Pamona. N:NC ratios, N:NC; N=1, NC=X

		Alveolar		**Bilabial**		**Velar**		**Affricate**	
		Initial	Medial	Initial	Medial	Initial	Medial		
NC̬ clusters	P1	1.8	1.3	1.8	1.2	---	---		
	P2	1.5	1.5	1.4	1.3	1.5	1.6		
	P3	1.7	1.5	1.5	1.2	--[4]	1.3		
	P4	1.7	1.4	1.7	---	---	---		
	P5	1.7	1.6	1.6	---	---	---		
	P6	1.4	1.4	1.5	1.4	1.4	1.6		
Average		**1.6**	**1.5**	**1.6**	**1.3**	**1.5**	**1.6**		
		Initial	Medial		Medial	Initial	Medial	Initial	Medial
NC̥ clusters	P1	2.4	2		1.9	---	---	2.3	1.8
	P2	1.9	1.9		1.8	2.4	2.4	1.6	1.7
	P3	2	2		1.8	2.3	2.4	1.8	1.5
	P4	2.2	2		2.1	---	---	2.3	1.8
	P5	2.5	2.2		1.7	---	---	2.2	2
	P6	1.6	1.7		1.6	1.9	2.9	1.6	1.6
Average		**2.1**	**2**		**1.8**	**2.2**	**2.6**	**2**	**1.7**

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[4] Due to the small number of repetitions, P3's initial velar ratio is not reliable.

5.5 Erromangan

As illustrated in chapter 2, section 2.2.4, the voiced alveolar NC sequence in Erromangan constitutes a single segment /^{n}d/, while the NC̥ sequences constitute clusters /mp, nt, ŋk/. At the alveolar place of articulation, therefore, Erromangan has a plain nasal, a plain voiceless stop, a voiced unary NC sequence, and an NC̥ cluster, while at the other places of articulation, all but the prenasalized stop are found. These sounds and sequences are illustrated for alveolars in the following figure.

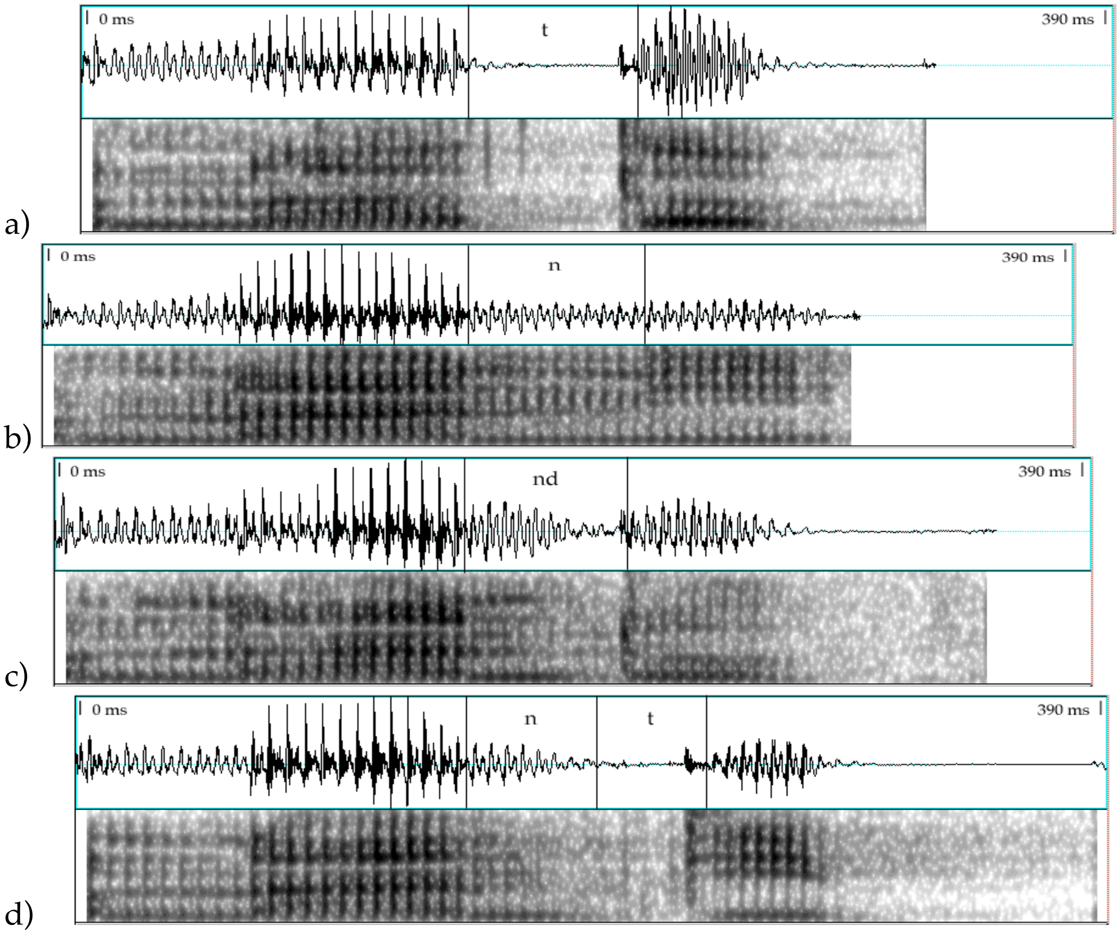

Figure 5.40: Erromangan. Representative waveforms and spectrograms of /natop/ ‘hair’ (a), /nani/ ‘goat’ (b), /na^{n}dup/ ‘bead tree’ (c), /nantip/ ‘banyan root’ (d) by E2. Window length is 390 ms each. Frequency on the Y-axis is 0-5000 Hz.

Figure 5.40 contains representative waveforms and spectrograms of each of these sound-types at the alveolar place of articulation word-medially, by E2: the /n/ from /na**n**i/ ‘goat’, /t/ from /na**t**op/ ‘hair’, /ⁿd/ from /na**ⁿd**up/ ‘bead tree’, and /nt/ from /na**nt**ip/ ‘banyan root’.

As seen in the figure, the unary segments /t/, /n/, and /ⁿd/ are all of similar length (here 82, 84, and 76 ms, respectively), with both /t/ and /ⁿd/ containing a brief release (10 ms and 5 ms, respectively). /nt/, which consists of a nasal closure, oral closure, and brief period of aspiration, is substantially longer than the others, here at 115 ms (52 ms nasal, 50 ms oral closure, 13 ms aspiration).

The duration data to be presented throughout this section consist of minimal or near-minimal sets comparing NCs with plain nasals and stops at the alveolar, bilabial, and velar places of articulation. (The language has no alveopalatal affricates.) As mentioned above, both NC̬ and NC̥ sequences are found at the alveolar place of articulation, but only NC̥ sequences are found at the bilabial and velar places of articulation. There are no plain voiced stops for comparison at any place of articulation.

Similar to the unary NC sequences in Tamambo, the Erromangan data reveal that the unary NC sequence is about the same duration as a plain nasal. The NC̥ clusters, however, are significantly longer than a plain nasal. This N:NC ratio in the cluster case is not always as great as it is in Pamona and Manado Malay, perhaps due to the different status of voicing in Erromangan, to be discussed in chapter 6, section 6.3.1. While statistical differences in duration between N and NC̥ were not presented for the previously discussed languages (as they were not as relevant to the discussion, and as the substantial differences in duration were obvious based simply upon examination of the box plots), these figures will be cited for Erromangan.

5.5.1 Erromangan- Alveolars

The following table 5.23 contains the minimal set for the alveolars in initial position. Duration data follow in figure 5.41.

Table 5.23: Target words for alveolars in initial position in Erromangan

Target sound	Token	Gloss
/n/	/**n**al/	*n*, mud
/t/	/**t**ais/	*n*, moon
/^{n}d/	/**^{n}d**al/	*p*, among
/nt/	/**nt**al/	*n*, taro

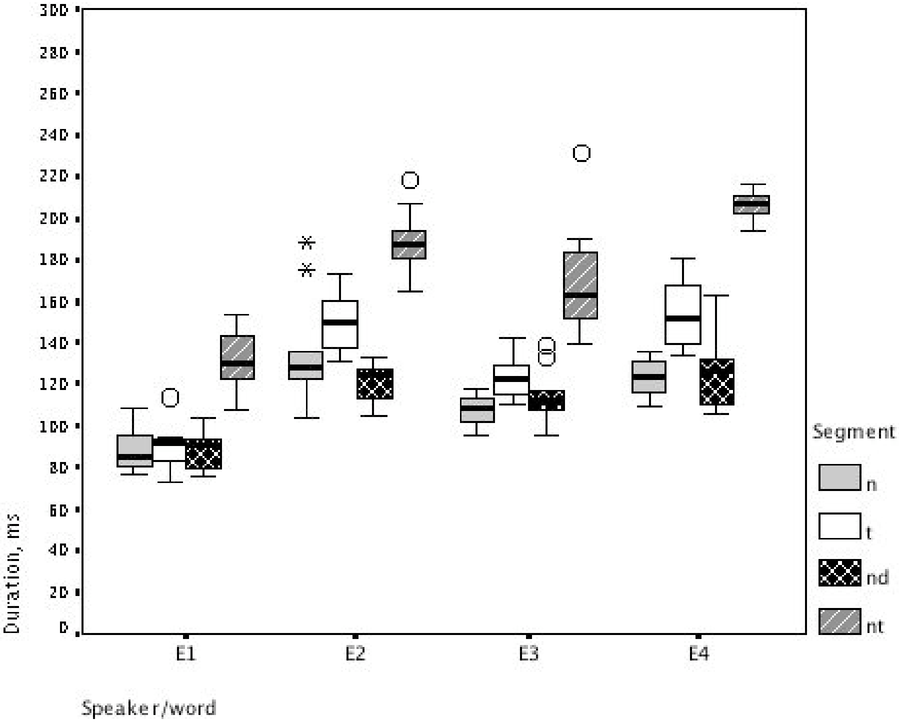

Figure 5.41: Erromangan. Duration of alveolars in initial position for ten repetitions (except: E1 /n/–5, /^{n}d/–7, /nt/–9; E2 /nt/–9; E4 /nt/–8). Difference between /n/ and /nt/ significant at p≤.001 for all speakers.

As seen above, /n/ and /^{n}d/ are equally the shortest sounds for all four speakers, while /nt/ is the longest. The duration of /t/ falls in between, except in the case of E1 where its duration is roughly the same as /^{n}d/. (Recall that aspiration is included in the total duration measurements of the voiceless stops.) Regarding the relationship between /n/ and /^{n}d/, the two sounds are essentially the same length for all speakers, with no statistically significant difference between the groups. This fact is consistent with the hypothesis that unary NC sequences have the duration of single segments. In the case of the relationship between /n/ and /nt/, the cluster is significantly longer than /n/ and also /t/ for all speakers, consistent with the hypothesis that a cluster is longer than a single segment. These data are supported by an additional alveolar set in initial position that contains similar results, presented in appendix E, figure E.1.

The near-minimal set for alveolars in medial position is in table 5.24 below. Although this set is not ideal given that the final syllable is open in the target word with the plain nasal but closed in the other forms, it is the best of the sets I was able to construct. (Data from two other sets were collected that appeared to be better candidates—/ta**n**i, ta$^{\mathbf{n}}$**d**i, ta**nt**i/ and /se**n**i, se$^{\mathbf{n}}$**d**i, se**nt**i/—but speakers appeared to confuse the NÇ̬ and NÇ̥ forms during the recording task.) However, the results from the medial set are confirmed by the data from the initial set above (where all words have final codas), and thus the medial data are considered sufficiently reliable. Duration data follow in figure 5.42.

Table 5.24: Target words for alveolars in medial position in Erromangan

Target sound	Token	Gloss
/n/	/na**n**i/	*n*, goat[5]
/t/	/na**t**op/	*n*, hair
/ⁿd/	/na**ⁿd**up/	*n*, bead tree
/nt/	/na**nt**ip/	*n*, banyan root

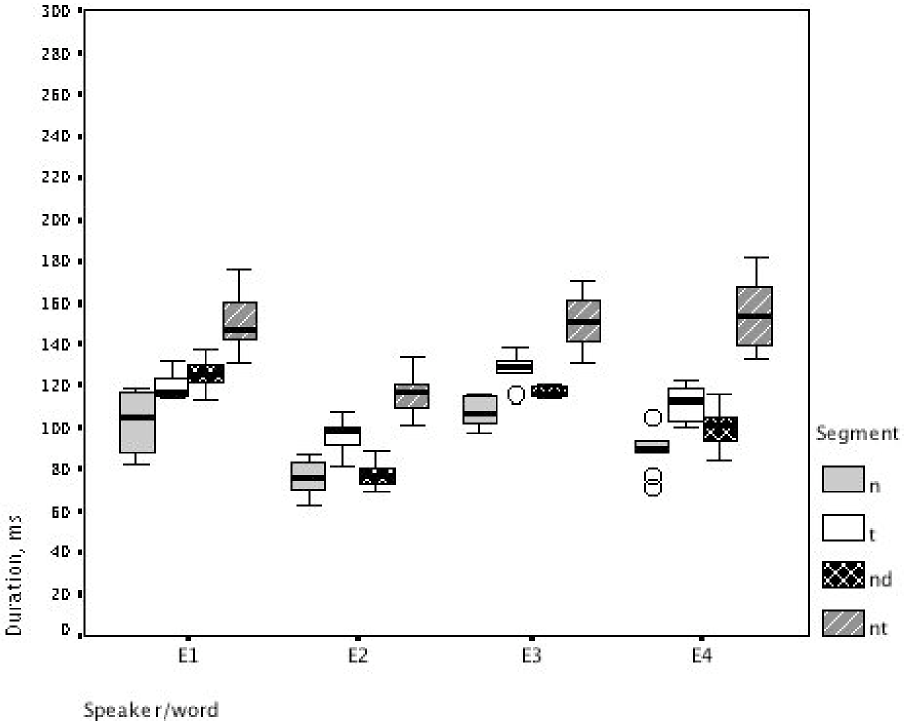

Figure 5.42: Erromangan. Duration of alveolars in medial position for ten repetitions (except: E4 /t/–7). Difference between /n/ and /ⁿd/ significant at p≤.001 for E1; p≤.01 for E3, E4. Difference between /n/ and /nt/ significant at p≤.001 for all speakers.

For speakers E2-E4, /n/ and /ⁿd/ are the shortest sounds, while for E1, /n/ alone is shortest; for all of the speakers, /nt/ is the longest, with /t/ generally falling in between. Regarding the relationship between /n/ and /ⁿd/, for speaker E2, there is no difference between the two groups. For the other three speakers,

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[5] This word is a borrowing from Bislama, commonly used in Erromangan.

although there is a significant difference in duration between the two sounds, it is still relatively small, as compared to data from Manado Malay and Pamona clusters, for example, with some overlap between the groups for all of the speakers, supporting the hypothesis that unary NC sequences have the duration of single segments. The difference between /n/ and /nt/ is highly significant for all speakers with no overlap between the groups, in accordance with the hypothesis that a cluster of two segments will be longer than a single segment. The n:nt difference is not as great as it is in the other languages, however, a point to be discussed in more detail in chapter 6, section 6.1.3. Overall, the medial and initial data for Erromangan alveolars are in agreement, with essentially the same N:NC relationships observed in both word positions. Further, the relationship between plain /n/ and unary /^{n}d/ is the same in Erromangan as in Tamambo, the other language in this study with unary NC sequences.

The following bar graph displays the average durations of the component parts of the NC sequences and their corresponding plain segments.

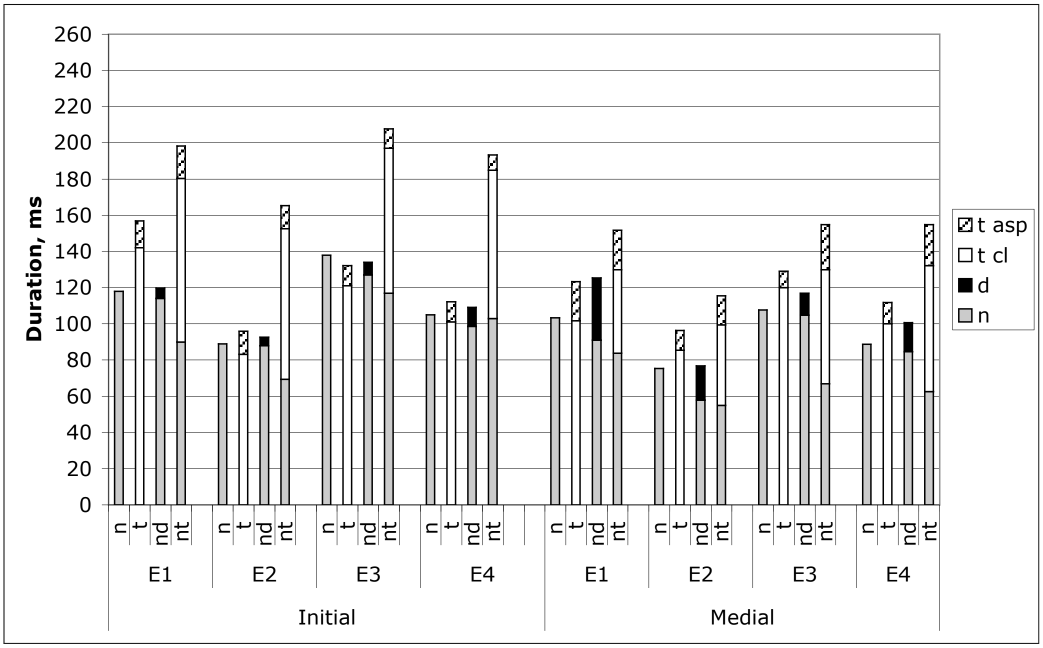


Figure 5.43: Erromangan. Average durations of component parts of alveolars in initial and medial position, based upon data in figures 5.41 and 5.42. [Note: "nd" represents /ⁿd/.]

As seen above, the majority of an /ⁿd/ sequence in Erromangan consists of a nasal closure, followed by a brief oral portion, an average range across speakers of 5-34 ms (the 34 ms average for E1's medial /ⁿd/ being unusually high). In medial position, this generalization still holds, although the oral release is somewhat longer, particularly for E1. The comparable lengths of /n/ and /ⁿd/ typically mean that the nasal closure in /ⁿd/ is shorter than in a plain /n/. Regarding /nt/, the duration of the nasal closure is similar to, or shorter than, that found in a simple nasal, while the length of the oral phase is shorter when in a sequence than a simple segment. The amount of the oral phase attributed to aspiration is relatively stable whether in a plain /t/ or /nt/, an average range across speakers of 8-25 ms, with two speakers (E3 and E4) actually having more aspiration on average in /nt/ than /t/ medially.

5.5.2 Erromangan- Bilabials

Bilabial NCs do not occur initially in Erromangan, and therefore only medial data are presented below. The medial set in Erromangan includes /m/, /p/, and /mp/, with no voiced obstruent for comparison (as the language lacks both /b/ and /^{m}b/). The near-minimal set of target words is in table 5.25 below. Duration data follow in figure 5.44.

Table 5.25: Target words for bilabials in medial position in Erromangan

Target sound	Token	Gloss
/m/	/na**m**ou/	*n*, mother
/p/	/na**p**a/	*v*, to multiply
/mp/	/na**mp**o/	*n*, whitewood tree

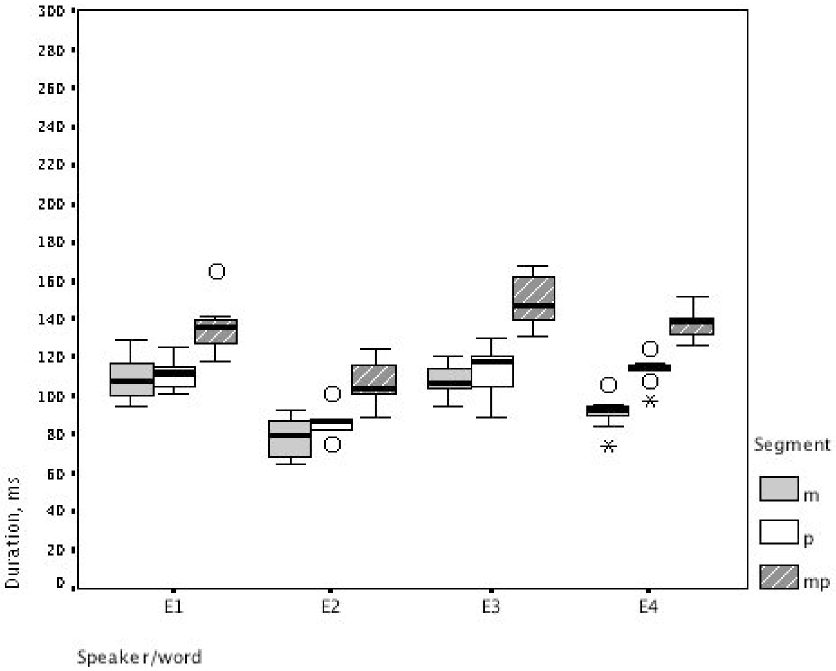


Figure 5.44: Erromangan. Duration of bilabials in medial position for ten repetitions (except: E1 /mp/–9; E2 /m/–9; E4 /p/–9). Difference between /m/ and /mp/ significant at p≤.001 for all speakers.

As seen above, /m/ and /p/ are equally short for three speakers, while /m/ alone is the shortest for E4. /mp/ is the longest sound for all of the speakers. Regarding the relationship between /m/ and /mp/, the cluster is significantly longer for all of the speakers, reflecting the generalization that clusters are longer than unary segments; however, this difference is not as great as it is at the other places of articulation in Erromangan, nor is it as great as it is for the m:mp contrast in the other languages. A possible reason for the smaller difference in Erromangan, the lack of voicing distinction at this place of articulation in the language, is considered in chapter 6, section 6.1.3.

Figure 5.45 below contains the average durations of the component parts of the sounds.

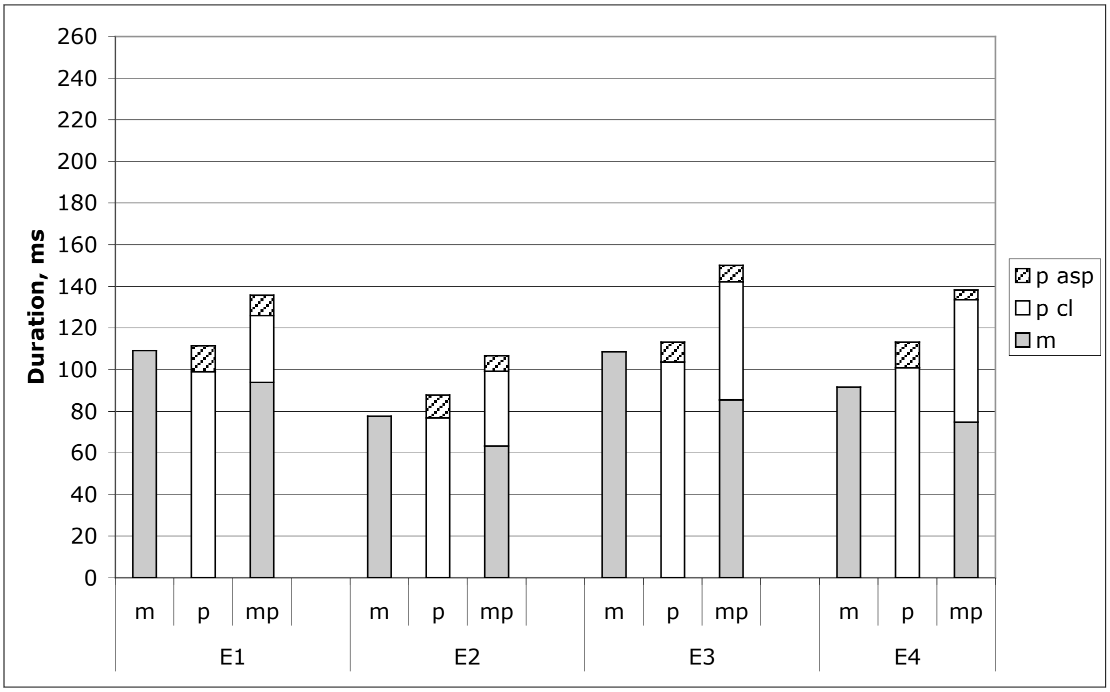


Figure 5.45: Erromangan. Average durations of component parts of bilabials in medial position, based upon data in figure 5.44.

As seen above, the average nasal closure in /mp/ is slightly shorter than it is in a plain /m/. The oral phase of the sequence is substantially shorter when in a cluster than a plain /p/, and this shortening is more pronounced in Erromangan than the other languages. Aspiration comprises a very small portion of the oral phase, an average range across the speakers of 5-12 ms, whether in a cluster or single segment.

5.5.3 Erromangan- Velars

Velars NCs do not occur initially in Erromangan, and therefore only medial data are presented. The velar data in medial position include /ŋ/, /k/, and /ŋk/, with no voiced obstruents for comparison, as was the case with bilabials as well. The near-minimal set of target words is in table 5.26 below. The set is not ideal given the closed final syllable in the target word for plain /ŋ/ while the other target words have open final syllables, but this is the best set I was able to construct. Duration data follow in figure 5.46.

Table 5.26: Target words for velars in medial position in Erromangan

Target sound	Token	Gloss
/ŋ/	/no**ŋ**un/	*n*, mouth
/k/	/no**k**i/	*n*, coconut
/ŋk/	/no**ŋk**u/	*n*, beach

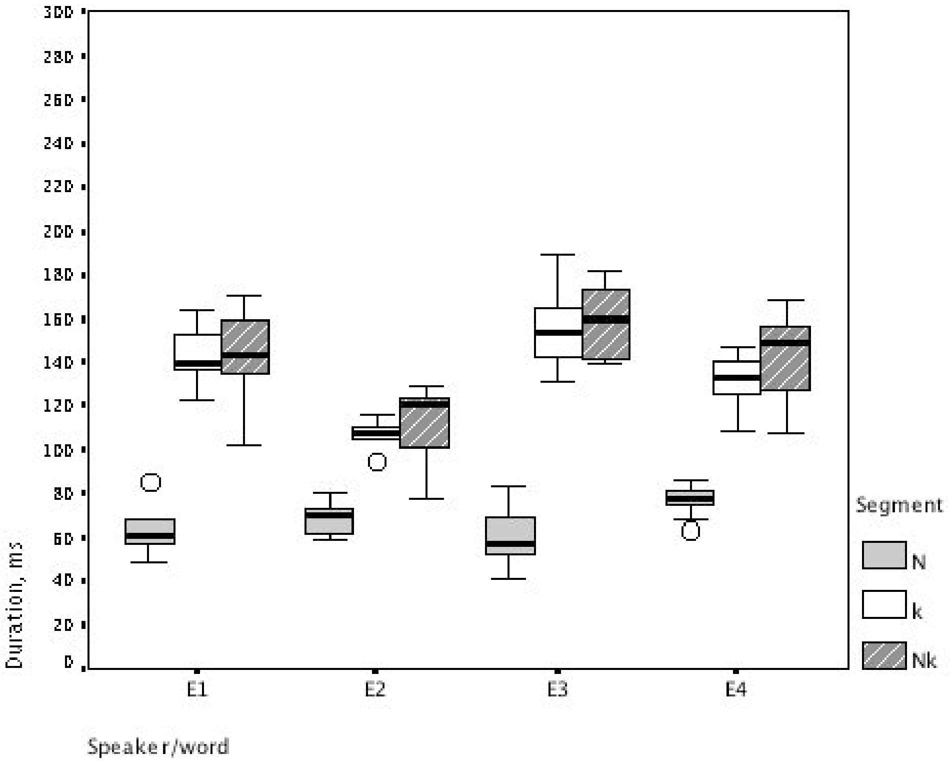


Figure 5.46: Erromangan. Duration of velars in medial position for ten repetitions (except: E1/ŋ/–6; E2 /ŋk/–9, /ŋ/–7; E4 /ŋk/–9, /ŋ/–9). Difference between /ŋ/ and /ŋk/ significant at p≤.001 for all speakers. [Note: "N" represents /ŋ/.]

For all four speakers, /ŋ/ is the shortest sound, while /k/ and /ŋk/ are equally the longest. Regarding the relationship between /ŋ/ and /ŋk/, the cluster is substantially longer than /ŋ/ for all of the speakers, consistent with the unary-cluster distinction. The equality in length of /k/ and /ŋk/ (there is no significant difference between the durations for any of the speakers), is especially interesting as this relationship between a plain voiceless stop and NÇ̥ sequence is not witnessed in any of the other languages, or for the other places of articulation in Erromangan. /k/ appears to be a particularly long segment in Erromangan.

Duration of the component parts is illustrated in figure 5.47 below.

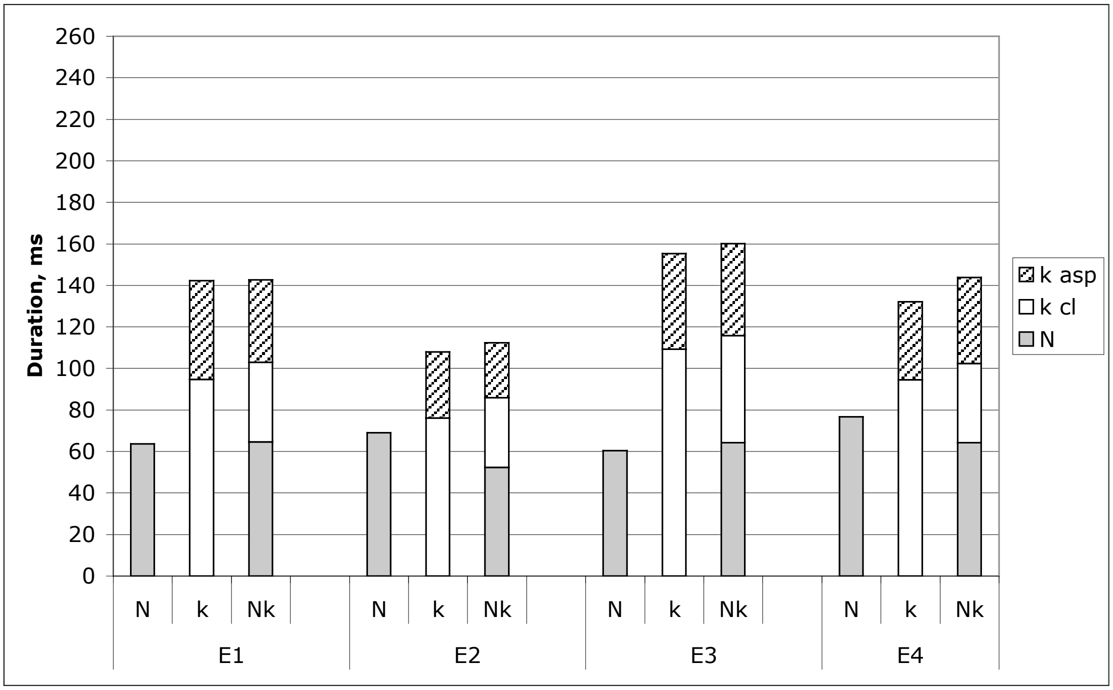


Figure 5.47: Erromangan. Average durations of component parts of velars in medial position, based upon data in figure 5.45. [Note: "N" represents /ŋ/.]

As seen above, the average duration of nasal closure in /ŋk/ is quite similar to that in plain /ŋ/. The oral phase of the cluster is significantly shorter than that of a plain /k/, although this shortening is not as pronounced as that seen for the bilabials above. As with other places of articulation in Erromangan and across the other languages as well, the aspiration period remains relatively stable between /k/ and /ŋk/, not varying relative to the total duration of the oral phase, an average range across speakers of 26-47 ms. The aspiration seen here for the Erromangan velars, however, is substantially longer than that observed at other places of articulation in the language, or for the velars of the other languages. This longer period of aspiration likely accounts for the /k/'s being substantially longer than the voiceless stops at the other places of articulation.

5.5.4 Erromangan summary

In Erromangan, the voiced alveolar NC sequence /ⁿd/ constitutes a unary segment, and this segment is essentially the same length as a plain alveolar nasal, in both medial and initial word position. The Erromangan data, therefore, like the Tamambo data, support the hypothesis that a unary NC sequence has the duration of a single segment. The NC̥ sequences in Erromangan—/nt, mp, ŋk/—constitute clusters. In these cases, the cluster is significantly longer than the corresponding plain nasal, supporting the hypothesis that a cluster is substantially longer than a single segment. Interestingly, however, the duration difference between a plain nasal and NC̥ cluster is not as great in Erromangan as it is in the other languages. I propose in chapter 6, section 6.1.3, that this difference is related to the status of voicing in the language. A table of the N:NC ratios in Erromangan follows. These ratios will be referred to in later discussion when comparing the languages.

Table 5.27: Erromangan. N:NC ratios, N:NC; N=1, NC=X

	Alveolar				**Bilabial**	**Velar**
Unary ᴺC̬, NC̥ cluster	NC̬		NC̥		NC̥	NC̥
	Initial	Medial	Initial	Medial	Medial	Medial
E1	1	1.2	1.7	1.4	1.2	2.2
E2	1	1	1.5	1.5	1.4	1.6
E3	.9	1.1	1.4	1.4	1.4	2.7
E4	1.1	1.1	1.6	1.8	1.5	1.9
Average	**1**	**1.1**	**1.6**	**1.5**	**1.4**	**2.1**

5.6 Summary

In this chapter, I investigated the two duration-related hypotheses presented at the outset, with data from NC sequences and corresponding plain segments at various places of articulation, and in different word positions, from four languages. The results reveal that both hypotheses are true. Hypothesis 1 states that unary NC sequences are equivalent in duration to single segments. This statement is supported by the data from Tamambo and Erromangan, both of which contain prenasalized stops of equivalent duration to plain nasals. Hypothesis 2 states that NC clusters are substantially longer than single segments. This statement is supported by the data from Manado Malay and Pamona, where voiced NC clusters are substantially longer than single segments, a difference that is more pronounced at the alveolar and velar places of articulation than at the bilabial place. Data from NC̥ clusters in Manado Malay, Pamona, and Erromangan are also consistent with this hypothesis, given that NC̥ cluster durations are longer than plain segments. The patterns in Erromangan differ in several interesting ways from the other languages, however, for reasons to be discussed in chapter 6, section 6.1.3.

The durations of the component parts of NC sequences and their corresponding plain segments were also considered. In general, it was found that voiced NC sequences, regardless of phonological status, are composed primarily of a nasal closure, followed by only a brief oral release. In NC̥ stop sequences, however, there is always a substantial oral closure, as well as an oral release, even though the duration of the oral portion is shorter than it is in a plain voiceless obstruent. Voiceless stops are articulated with a brief period of aspiration in each of the languages. Whether occurring independently or as part of an NC sequence, the duration of aspiration remains fairly steady, not differing in accordance with the duration of the oral closure or the total duration of the segment. Finally, while the realizations of the NC stop sequences are quite consistent across the speakers of a language and even across the languages (i.e. voiced NC sequences never contain a notable oral closure), the realizations of the affricates vary. In particular, in the NC affricate sequences, some speakers have a substantial oral closure followed by a fricated release while others have only a fricated release.

In the following chapter, I continue the discussion of duration. Both total duration and relative duration of the component parts are explored further, through a comparison of the languages.

CHAPTER SIX:
DISCUSSION AND CONCLUSIONS

In this chapter, I return to the primary question under investigation in this thesis—*Are there distinct NC patterns in the phonology, and are these patterns reflected in the phonetics?*—and discuss the answers in light of the phonological and phonetic data presented in the preceding chapters. The structure of this chapter is as follows. In the first few sections, sections 6.1-6.3, I review the acoustic data presented in chapter 5 through a comparison of the four languages, with a discussion of total duration in 6.1, a discussion of relative nasal-oral timing in 6.2, and methodological conclusions in 6.3. Then, in the next two sections, I discuss implications of these data, with a discussion in section 6.4 of how the phonological NC pattern gaps (identified in chapter 2, section 2.1) have phonetic explanations, and a discussion of phonological representations and their implications in section 6.5. Chapter conclusions are in section 6.6, and a thesis summary and conclusions are in section 6.7.

6.1 Total duration- Acoustic results

The data in chapter 5 revealed that NC clusters and unary NC segments do differ phonetically: NC clusters are substantially longer than unary NC segments or prenasalized stops. Since arguably no language contrasts the two NC-types within its inventory, the determination of relative durations must be made by comparing various segment-types within a language and then comparing the ratios of plain segments to NC sequences. As seen in chapter 5, it is the relationship between the duration of a plain nasal and of an NC sequence that is the most informative in this regard. In what follows, I illustrate how the data support Hypothesis 1—that unary NC segments are equivalent in length to comparable unary segments in a language, and Hypothesis 2—that NC clusters are substantially longer than comparable plain segments—by presenting graphs that compare N:NC ratios across the languages. Voiced NC stop sequences are addressed in 6.1.1, NC affricates in 6.1.2, and NC̥ stop sequences in 6.1.3.

6.1.1 Voiced NC sequences

The data from voiced NC sequences support both hypotheses, with the alveolar data providing the clearest evidence. The unary /ⁿd/ segments in Tamambo and Erromangan are essentially the same length as /n/, while the /nd/ clusters in Manado Malay and Pamona are significantly and substantially longer than /n/. These data are displayed in the following graph of ratios. For each language, the n:nd relationship, where /n/=1, was calculated for both initial and medial position for each speaker (as seen in the various summary tables in chapter 5), and these values were then compared across the speakers. Note that while /n/=1, the scale is set at .08 to illustrate that some values fall below 1 (meaning that in some cases, the average duration of NC was actually shorter than that of /n/).

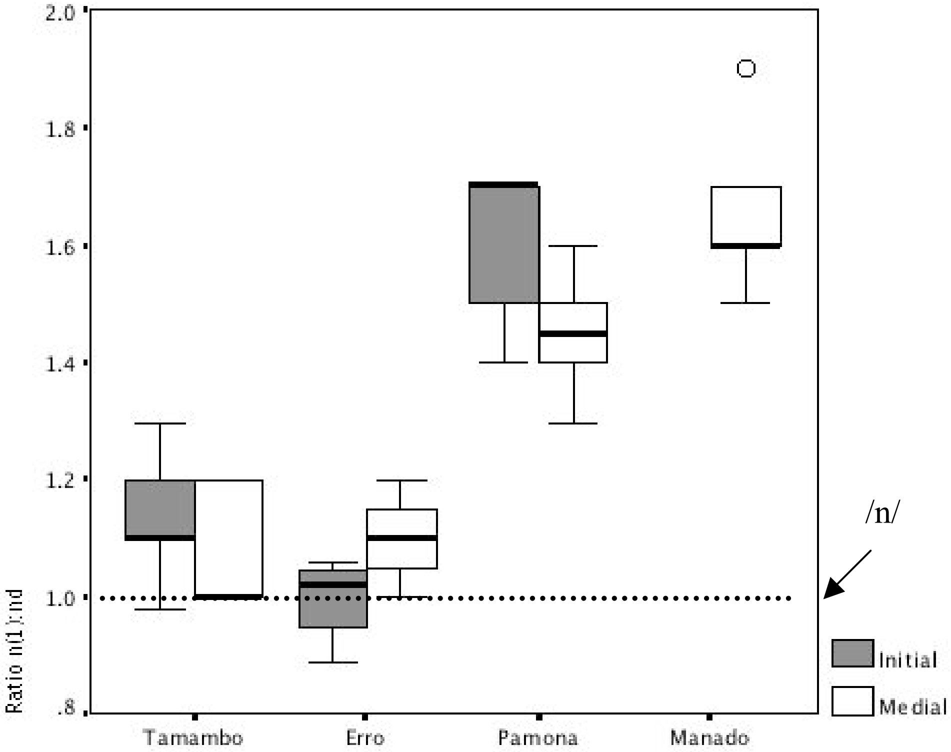


Figure 6.1: Average n:nd ratios in initial and medial position, across the speakers of each language, based upon data in chapter 5 (figures 5.6, 5.7, 5.17, 5.27, 5.28, 5.41, 5.42); /n/=1.

As seen above, the languages cluster into two general groups. For Tamambo and Erromangan, the languages with unary /ⁿd/ segments, the ratio ranges from 1:.9 to 1:1.3, the median value being right at 1:1 for medial position in Tamambo and initial position in Erromangan. Since /n/= 1, this means that the duration of /ⁿd/ is very similar to the duration of /n/. Pamona and Manado Malay, the languages with /nd/ clusters, form another group, with ratios in medial position ranging from 1:1.3 to 1:1.6 for Pamona and 1:1.5 to 1:1.7 for Manado Malay (with an outlier at 1:1.9), and ratios in initial position from 1:1.4 to 1:1.7 in Pamona. (There are no initial NCs in Manado Malay.) The alveolar data, therefore, clearly support both hypotheses.

Turning to the voiced bilabial sequences, the data clearly support Hypothesis 1: unary NC sequences are about the same length as plain nasals. As for Hypothesis 2, some of the data support the hypothesis, that NC clusters are longer than single segments, while some do not. A graph of m:mb ratios is in figure 6.2 below. (Data for Erromangan are not included as the language has no /mb/.)

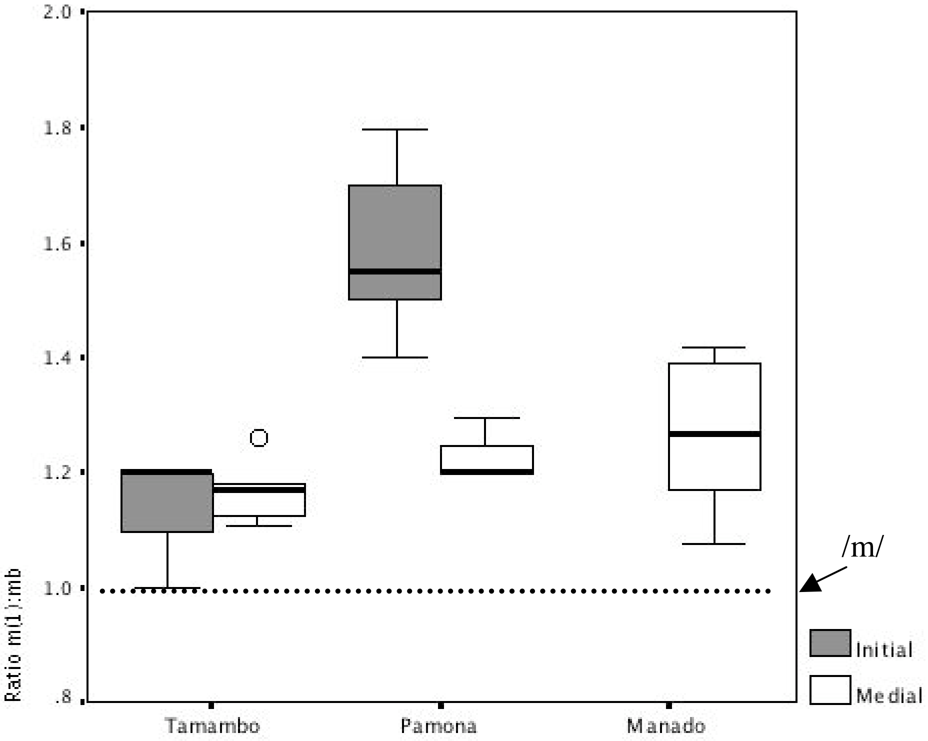


Figure 6.2: Average m:mb ratios in initial and medial position, across the speakers of each language, based upon data in chapter 5 (figures 5.9, 5.10, 5.14, 5.30, 5.31); /m/=1.

As seen above, the m:mb ratio in Tamambo, where the NC sequences form unary segments, ranges from 1:1.1 to 1:1.2; since m=1, this means that the total duration of /^{m}b/ is very close to that of /m/. This pattern is similar to that for the alveolars in the language. The Tamambo bilabial data, therefore, in both initial and medial position, support that claim that unary NC sequences are similar in duration to single segments. For the Pamona /mb/ clusters, a different pattern is seen in initial and medial position. Initially, the m:mb ratio is relatively large, ranging from 1:1.4 to 1:1.8, indicating that an /mb/ cluster is significantly and substantially longer than a plain /m/ for all speakers. In medial position, however, although the difference is in the right direction, the ratio is much smaller, ranging from 1:1.2 to 1:1.3, indicating that medial /mb/ is not that much longer than /m/ and that the difference between Pamona and the unary NC language Tamambo is not as robust. A possible analysis of languages with NC patterns like Pamona (not advocated here) is that the initial sequences are unary while the medial sequences are clusters. The data in this graph are therefore particularly interesting, because if such an analysis were correct, one would expect the opposite pattern than that seen here—where the initial sequences have a smaller ratio than the medial sequences. The medial data in Manado Malay are somewhat mixed with regard to the claim that NC clusters are longer than single segments. The /mb/ ratio ranges from about 1:1.1 to 1:1.4, indicating that for some speakers, there is little difference between the durations of /m/ and /mb/, as would be expected for unary segments rather than clusters, and for other speakers there is a significant difference, in line with the expectations about clusters. In any case, although the ratio in Manado Malay is greater overall than in Tamambo, it is only moderately so and does not hold for all of the speakers, and it is certainly not as substantial as the difference seen in case of the alveolars.

The medial m:mb ratio for clusters, therefore, is difficult to interpret with regard to the claim that NC clusters are longer than unary segments. However, since the bilabial medial clusters are the only sequences that do not strongly support the hypothesis across the places of articulation and languages, and since the bilabials exhibit other unexpected behaviors (such as their longer oral phases in unary Tamambo, as seen in chapter 5, section 5.2.2), these cases may require an independent explanation and should not necessarily be viewed as counterexamples.

Turning to the voiced velar sequences, there are no unary examples to compare to clusters. However, it may still be worthwhile to consider the /ŋ/ to /ŋg/ ratios in the cluster languages, to see if they pattern in line with expectations that clusters will be longer than unary segments. As already discussed, the velar data posed labeling difficulties, and therefore there is only a small amount of data available. The results in the following graph, therefore, should be viewed as preliminary.

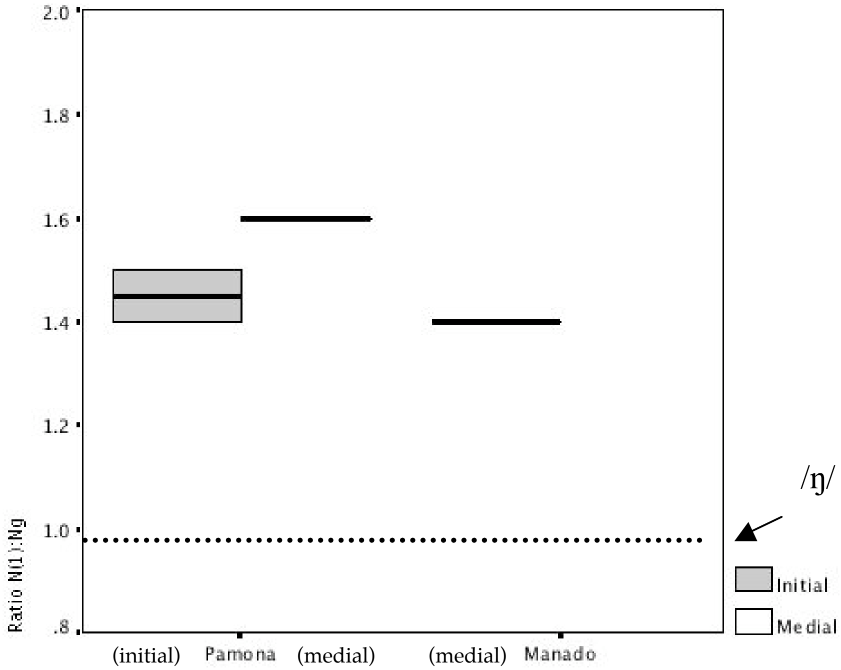
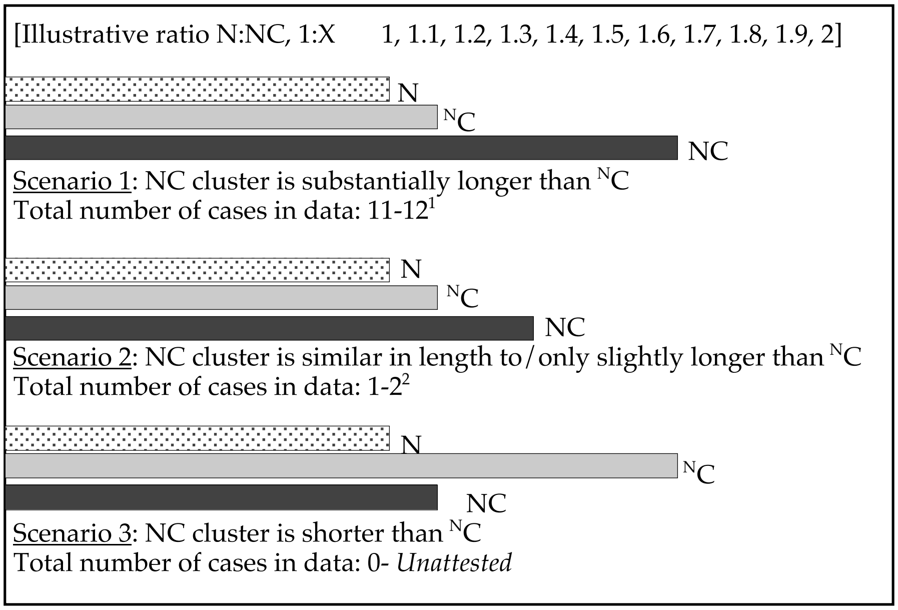


Figure 6.3: Average ŋ:ŋg ratios in initial and medial position, across speakers of each language, based upon data in chapter 5 (figures 5.21, 5.33, 5.34); /ŋ/=1. [Note: "N" represents [ŋ].)

As seen above, the ŋ:ŋɡ ratio in all three cases above ranges from about 1:1.4 to 1:1.6. (The boxes do not appear for the data in medial position given that the ranges are so narrow.) This indicates that /ŋɡ/ is substantially longer than /ŋ/ in both initial and medial position in Pamona, and in medial position in Manado Malay. Although these data are only preliminary, they suggest that the velars are consistent with the claim that clusters are longer than unary segments. The velar data also support the idea that the alveolar pattern—where clusters are longer than unary segments—is the basic pattern, and that the bilabial pattern, which exhibits more variability in medial position, is the exception.

In addition to looking at the available data and how they relate to the claim that cluster NCs are longer than unary NC segments, it is valuable to consider what the data *do not* reveal. In most of the data, NC clusters are substantially longer than plain nasals while unary NC segments are roughly the length of plain nasals, or only slightly longer. In a subset of the data, both unary NCs and NC clusters are only slightly longer than plain nasals. In *no* set of the data, however, are NC clusters about the same length as plain nasals while unary NCs are longer. If earlier claims that NC clusters and unary NC segments do not have unique phonetic patterns are true, then there is no logical reason why this opposite pattern should not be observed. These generalizations about the data are schematized in figure 6.4 below.



[Illustrative ratio N:NC, 1:X 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2]

Scenario 1: NC cluster is substantially longer than ^{N}C
Total number of cases in data: 11-12[1]

Scenario 2: NC cluster is similar in length to/only slightly longer than ^{N}C
Total number of cases in data: 1-2[2]

Scenario 3: NC cluster is shorter than ^{N}C
Total number of cases in data: 0- *Unattested*

Figure 6.4: Schema of possible NC - ^{N}C relationships and which are attested in data

Finally, another important observation from the data is that there is a very strong tendency for the speakers of a language to have the same NC duration patterns. For example, all Tamambo speakers have short unary NC sequences and all Manado Malay speakers have long cluster NC sequences. If it were the case that there is no phonology-phonetics relationship with regard to these sequences, then we might expect greater variation, with some speakers of the same language having long sequences and other speakers having shorter ones.

Given the evidence that the two NC-types do have distinct phonetic patterns, it is interesting to reflect on the phonological status of the sequences in Pamona. In this language, the phonological status of the sequences is somewhat less clear, and some might argue that the sequences form unary

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[1] Tamambo- initial and medial alveolars, initial and medial bilabials; Manado Malay- medial alveolars, medial bilabials for some speakers, medial velars; Pamona- initial and medial alveolars, initial and medial bilabials, initial and medial velars; Erromangan- initial alveolars

[2] Pamona- medial bilabials; Manado Malay- medial bilabials for some speakers

segments rather than clusters. Not only do the phonetic data support their analysis as clusters, given that the NC sequences in the language are substantially longer than plain nasals, but the consistency across the speakers suggests that individuals do not vary in their phonological representation; rather, for all Pamona speakers, the sequences form clusters.

6.1.2 NC Affricates

In addition to distinct unary and cluster NC stop sequences, there are distinct unary and cluster NC affricate sequences. In Pamona and Manado Malay, nasals may be followed by either a voiced or voiceless affricate (/ndʒ, ntʃ/). (Only data from the voiceless affricates were presented in chapter 5, due to segmentation difficulties with the voiced sequences.) Tamambo, on the other hand, has a unary NC affricate /ⁿdʒ/ which is consistently produced by speakers (in the present study) with a voiceless oral portion. Given the different phonological NC structures, the affricates provide another opportunity to compare the phonetics of unary segments and clusters; however, the affricate data also present several complications which make the data more difficult to interpret.

In the case of the voiced stops, unary NCs were found to be roughly equal in duration to simple segments. However, the expectations are necessarily different for /ⁿdʒ/, due to the period of frication, and due to the fact that the Tamambo speakers in this study devoice the oral portion. Given that the frication and voicelessness of the oral portion will contribute to increased duration (as discussed in chapter 5, section 5.2.3), this sound will likely be longer than a plain nasal or a prenasalized voiced stop, for reasons unrelated to phonological structure. In addition, the plain nasals for comparison are alveolar rather than palatal, and as palatals are generally longer than alveolars, this too will have an impact on the results. In fact, the data in chapter 5, section 5.2.3 reveal that /ⁿdʒ/ is substantially longer than /n/. What does this mean for the hypotheses under investigation? The data from Tamambo alone do not necessarily tell us anything conclusive, given the complicating factors articulated above. However, it is still possible to compare unary /ⁿdʒ/ in Tamambo to cluster /ntʃ/ in the other languages, to see if such comparisons offer any insight. In the current data set, Manado Malay contains a clear /ntʃ/ cluster. Pamona also contains a /ntʃ/ sequence, and although it is analyzed as a cluster in this study (the realization of /n+s/), it does have a special status: the language has no plain /tʃ/, rather the sound only occurs with a preceding nasal, and it therefore shares characteristics with the unary sequence. Figure 6.5 below contains the average N:NC affricate ratios in these three languages.

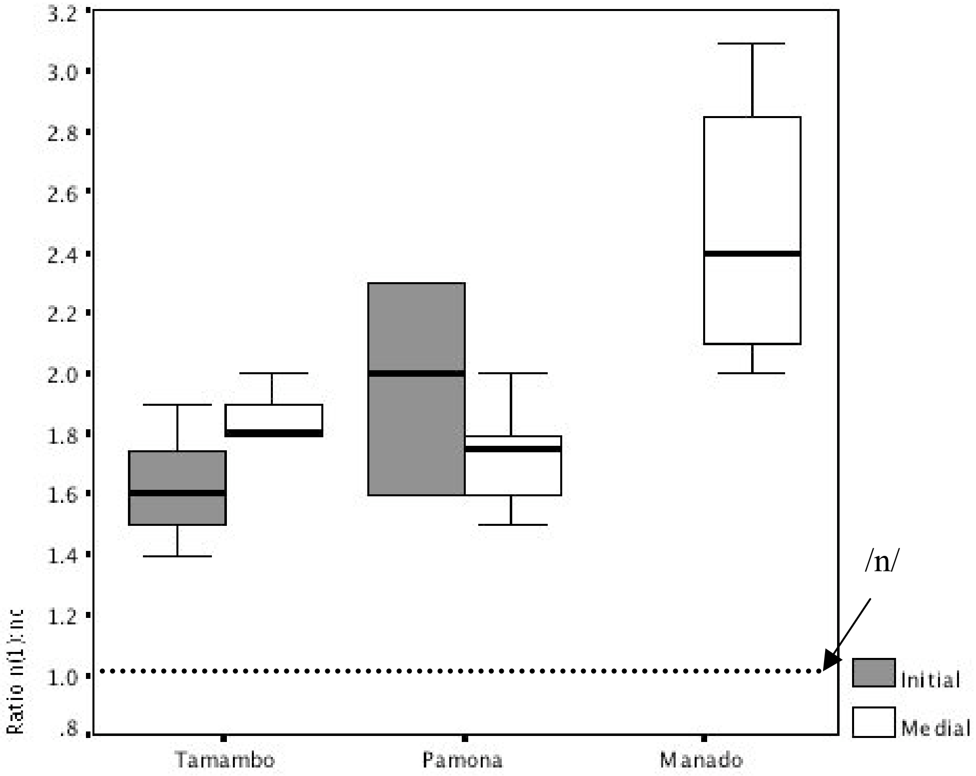

Figure 6.5: Average N:NC affricate ratios in initial and medial position, across the speakers of each language, based upon data in chapter 5 (figures 5.12, 5.13, 5.23, 5.36, 5.37); /n/=1.

As seen above, the N:NC affricate ratio in unary Tamambo ranges from about 1:1.4 to 1:1.9 in initial position, and 1:1.8 to 1:2 medially. In Manado Malay, where the sequence forms a clear cluster, the ratio in medial position ranges from about 1:2 to 1:3.1. The ratio for the clusters is therefore substantially larger than for the unary segments, with no overlap seen between the two groups. However, it is important to note there is wide-ranging inter-speaker variation, especially in the case of Manado Malay. In Pamona, the n:ntʃ ratio patterns more similarly to the unary segments in Tamambo than the clusters in Manado Malay. Although it is unclear how this patterning should be accounted for, it is possible that the Pamona /ntʃ/ sequences, in the absence of a plain /tʃ/, are exhibiting the phonetic characteristics of unary segments.

6.1.3 NC̥ sequences

Chapter 5 included data from NC̥ stop sequences. Since there are no unary NC̥ stops in these language (or any language, as argued in chapter 2, section 2.1), it is not possible to test the first hypothesis—that unary NC sequences are the duration of single segments. In the case of the NC̥ clusters, all of the data strongly support the second hypothesis—that clusters are substantially longer than single segments. However, since greater length is expected in an NC̥ sequence simply given the tendency for voiceless segments to be longer, these data are not especially illuminating. In any case, it is still worthwhile to compare the NC̥ data across the languages, and indeed some interesting differences emerge.

Given that all NC̥ stop sequences are clusters, one might expect that the various languages would exhibit similar N:NC̥ ratios; however, this is not the case. While Pamona and Manado Malay do tend to have similar N:NC̥ ratios, those in Erromangan are considerably smaller. These data are displayed in the following graph, which includes bilabials in medial position, and alveolars in both initial and medial position, in these three languages. It excludes the velars since the data for that place is preliminary.

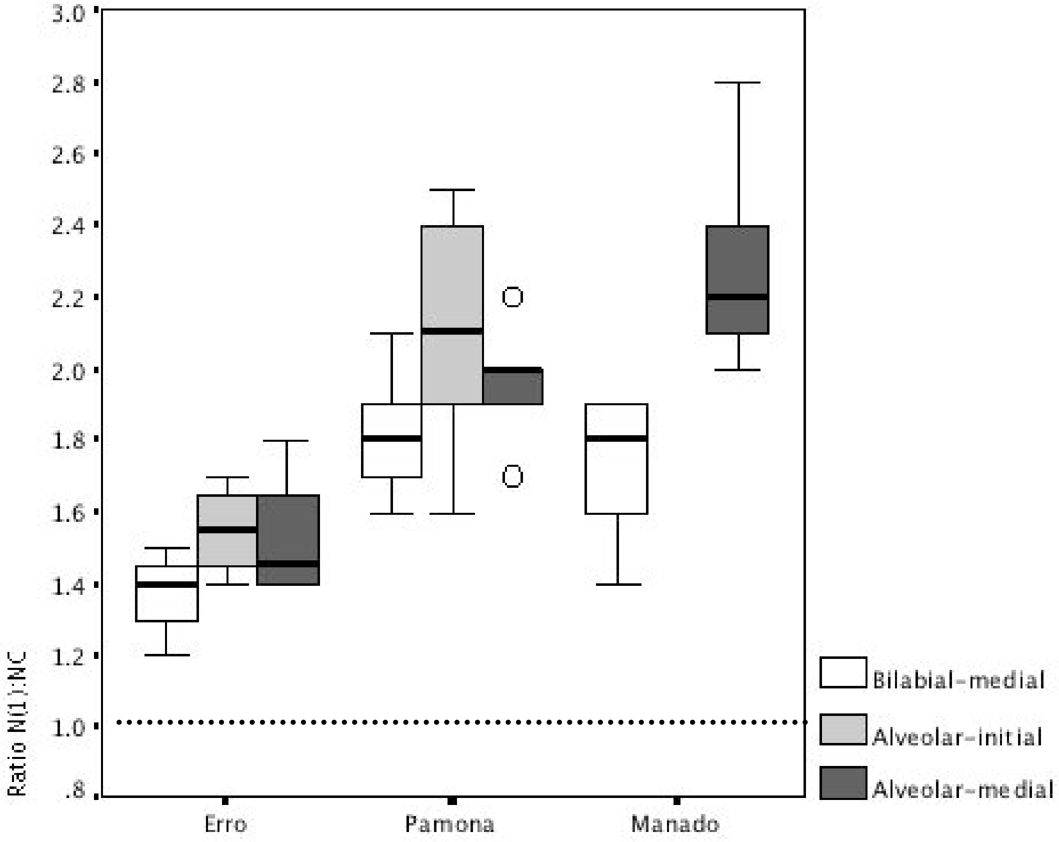

Figure 6.6: Average N:NC̥ ratios in initial and medial position, across the speakers of each language, based upon data in chapter 5 (figures 5.17, 5.19, 5.27, 5.28, 5.31, 5.41, 5.42, 5.44); N=1.

As seen in the above chart, there are large N:NC̥ ratios in each of the languages, meaning that the duration of a cluster is substantially longer than a plain nasal. However, the Erromangan ratios are much smaller than those in Pamona and Manado Malay. If the sequences form clusters in all of the languages, why should these differences exist?

A possible explanation for the smaller N:NC̥ ratio in Erromangan may be the role of voicing in the language. There are no voiced stops in Erromangan, other than the prenasalized /ⁿd/. Except at the alveolar place of articulation, therefore, it is not necessary for Erromangan speakers to distinguish between an NÇ̬ and an NÇ̥ sequence at the same place of articulation. In languages like Manado Malay and Pamona, which contrast /mb/ and /mp/, for example, the NÇ̥ sequence is significantly longer than the voiced sequence, which itself is significantly longer than the plain /m/. The duration difference between the two sequence-types is manifested largely in the oral portion of the sequence, which is much longer in the voiceless cases (as will be seen in section 6.2.3). While a distinct oral closure is not necessary to lend the percept of a voiced obstruent in the NÇ̬ cases, which are perceived as having voiced oral portions simply by virtue of having an oral release (and / or no nasal airflow on the following vowel, as discussed in chapter 4, section 4.4), a distinct oral closure is necessary to lend to the percept of a voiceless stop in the NÇ̥ cases and therefore a duration difference between NÇ̬ and NÇ̥ results. (See discussion of related points by Ohala and Ohala 1991, Westbury and Keating 1986, Hayes and Stivers 2000).

In Erromangan, however, the voiced sequence /mb/—whose duration falls between /m/ and /mp/ in Pamona and Manado Malay—is absent. One possible explanation for the smaller m:mp ratio, therefore, is as follows. In the absence of a contrasting NÇ̬ sequence, there is no motivation for speakers to maintain such a distinct oral closure in the NÇ̥ sequences: even if the oral portion of the sequence is perceived as voiced, there is no NÇ̬ sequence with which to confuse it. The result is that /mp/ sequences are shorter when not in contrast with /mb/, and therefore the difference between /m/ and /mp/ is not as great. In fact, the N:NC ratio at the bilabial place of articulation, where there is no voiced NC counterpart, is quite small in Erromangan (an average ratio of 1:1.4), while the ratio at the alveolar place of articulation, where there *is* a voiced counterpart and thus another sound that must be contrasted, is larger (an average ratio of 1:1.5 medially, 1:1.6 initially).

The Erromangan data are interesting in an additional way. As discussed in chapter 1, section 1.4, there seems to be some preference for voiced NC sequences cross-linguistically, and this preference is arguably articulatorily motivated. It would follow from the earlier discussion that the only reason for maintaining a voiceless obstruent in an NC̥ sequence would be to distinguish it from a corresponding voiced NC sequence. (In fact, Hayes and Stivers 2000 demonstrate that the tendency to voice post-nasal stops is present even in languages that must maintain a contrast.) The Erromangan data are therefore interesting in that, at the bilabial and velar places of articulation, where there are no voiced NC sequences, the obstruents in the NC̥ sequences are always voiceless. These data may suggest either that there are other competing motivations (rather than just articulatory) for an NC̥ sequence to maintain its voiceless oral closure, or that the arguments for greater articulatory ease in the voiced cases are not entirely accurate.

6.1.4 Summary- Total duration

It is evident from the above comparison of duration data across the languages that NC clusters are longer than unary NC segments. The clear prenasalized stops in Tamambo and Erromangan are always equivalent in length to comparable unary segments (i.e. same or marginally longer), while the NC clusters in Manado Malay and Pamona are almost always significantly and substantially longer than comparable unary segments (with some exception in the case of medial bilabials). These observations find support from several past studies reviewed in chapter 3, section 3.1.2. As discussed there, unary NC segments were found to be comparable in length to single segments in several languages including Ndumbea (Gordon and Maddieson 1999), while NC clusters were found to be substantially longer than plain segments in several languages including English (Vatikiotis-Bateson 1984). No past studies with clear phonological analyses and sufficient phonetic data contradict these findings.

Also clear from the above discussion is that it is the segmental status of the NC sequence (unary vs. cluster) that relates to phonetic duration, not the syllabification (tautosyllabic vs. heterosyllabic). This point is evident in the comparison of Pamona and Manado Malay. In both languages, the NC clusters are substantially longer than single segments, even though the clusters in Pamona are tautosyllabic, while the clusters in Manado Malay are heterosyllabic. The N:NC ratio does tend to be somewhat smaller in Pamona than in Manado Malay, an observation most evident for the alveolars. It might be the case that the differing syllabification of the nasals results in some small duration differences (as speculated by Riehl 2006a), as consonants have been shown to be articulated differently in different syllable positions. Krakow (1989), for example, investigates the articulation of onset vs. coda bilabial nasals and finds various differences. However, any differences resulting from syllable affiliation of the nasal are separate from the issue of duration differences based upon segmental status. The robust duration differences seen in this study clearly reveal that the phonetic timing is reflecting the phonological segmental status—unary vs. cluster—of the NCs.

As mentioned in chapter 3, section 3.1.1, the duration of segments may also be affected by the “compression effect”, whereby durations of words, independent of internal structure, remain fairly steady, resulting in a shortening of all segments with each additional segment added. (See e.g. Herbert 1975, Vatikiotis-Bateson 1984, Farnetani & Kori 1986.) If the compression effect is at work in these languages, then all NC clusters (regardless of syllable affiliation) would be expected to undergo some shortening, while prenasalized NCs would not, since the former consist of two segments and the latter only one. We therefore might expect the unary NC segments to have more stable duration, and the clusters to be more variable in duration, with potentially more factors affecting their durations. This possibility merely reinforces the observed length differences between unary and cluster NCs: even in light of the possible phonetic shortening of clusters due to the compression effect, NC clusters are still substantially longer than unary segments.

Another possible factor affecting total duration is moraic structure. This topic is not taken up in the present study, given that there is no evidence that nasals in any of these languages are moraic. However, when comparing languages that do differ in the moraic structure of nasals, one would expect differences in total duration, with moraic nasals being longer than non-moraic. Various studies, some of which are summarized in chapter 3, section 3.1.2, have investigated duration and moraic structure in NCs. A more explicit investigation of issues posed by languages with moraic nasals in NCs, as they relate to unary vs. cluster NC status, would be informative.

6.2 Duration of component parts of NC sequences

Throughout chapter 5, I presented bar graphs containing data on the average relative durations of the component parts of NC sequences and corresponding plain nasals and stops. In this section, I provide an overview of the data through a comparison of the languages. These data do not correlate with the phonological status of an NC sequence. In fact, the durations of component parts of these sound-types tend to be remarkably similar across the languages—in contrast to the differences observed in total duration.

The discussion in this section is based upon the acoustic data. Chapter 4, section 4.2, also contained discussion of the relative durations of nasal and oral airflow in NC sequences, based upon the nasal airflow data. Although I focus on the acoustic data here, for which far more data are available (a greater number of repetitions and speakers), I do refer to the airflow data at times. In general, the two sources of data corroborate one another, and the same observations are made from each. In section 6.2.1, I review the results for voiced NC sequences, including a discussion of whether or not prenasalized stops are distinct from another described unary NC-type, a post-stopped nasal. In section 6.2.2, I consider NC̥ sequences, and in section 6.2.3, I consider NC affricates.

6.2.1 Voiced NC sequences

While NC̬ clusters and unary segments differ significantly in terms of their total duration, in terms of relative nasal-oral timing, the two structures are very much alike. Bar graphs included throughout chapter 5 provide information about the durations of the component parts of NC sequences and corresponding plain segments. These graphs, along with the airflow data in chapter 4, reveal an important similarity between unary and cluster voiced NC sequences: in both cases, the duration is composed almost entirely of a nasal closure, followed by only a brief oral portion (closure and release). The following graph contains medial alveolar data from a representative speaker of each language.

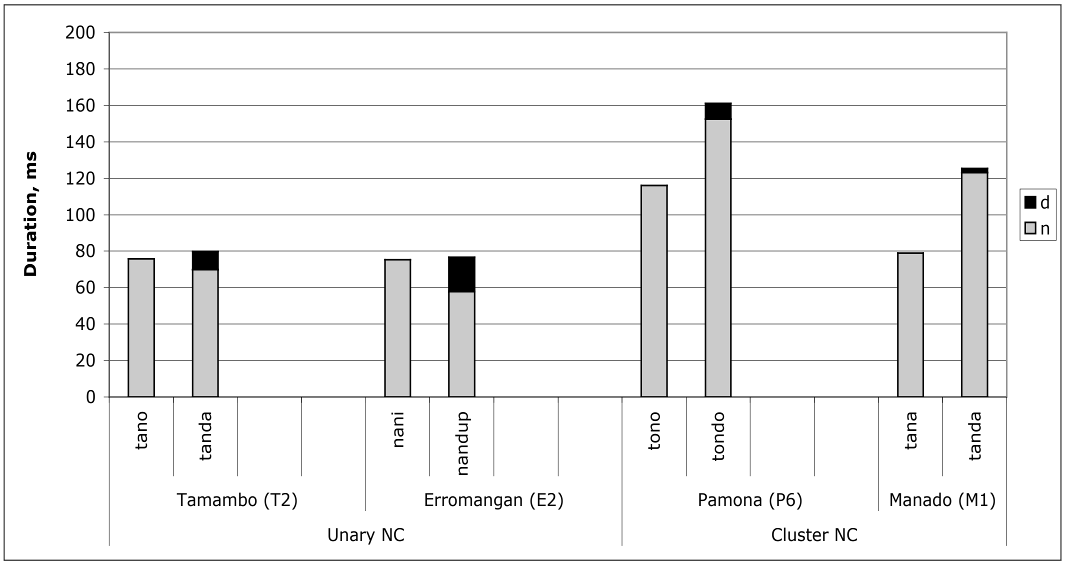

Figure 6.7: Average durations of component parts of /n/ and /nd/ in medial position from one representative speaker of each of Tamambo, Erromangan, Pamona, and Manado Malay, based upon data in chapter 5 (figures 5.17, 5.28, 5.42).

As seen above, whether the sequence is unary, as in Tamambo and Erromangan, or a cluster, as in Pamona and Manado Malay, most of the sequence is composed of a nasal closure. This means that in the cluster languages, where the total duration of the sequence is longer, the nasal portion in the sequence is longer than a plain nasal, while in the unary languages, the nasal portion of a sequence is on average slightly shorter than a plain nasal. These generalizations hold across places of articulation and word position. This is a striking observation since a priori we would expect the nasal and oral portions to be roughly equal. These data are consistent with other studies, discussed in chapter 4, section 4.3.1, that found voiced NC sequences to be almost entirely nasal.

The duration of the oral portion of an NC sequence is remarkably consistent across speakers and repetitions. It also does not vary in accordance with the total duration of an NC sequence. This can be seen, for example, in figure 6.8 below, where a speaker of Manado Malay has a very short oral closure for /nd/ (<2 ms) in both a 95 ms token and a 137 ms token of /tanda/ 'sign'.

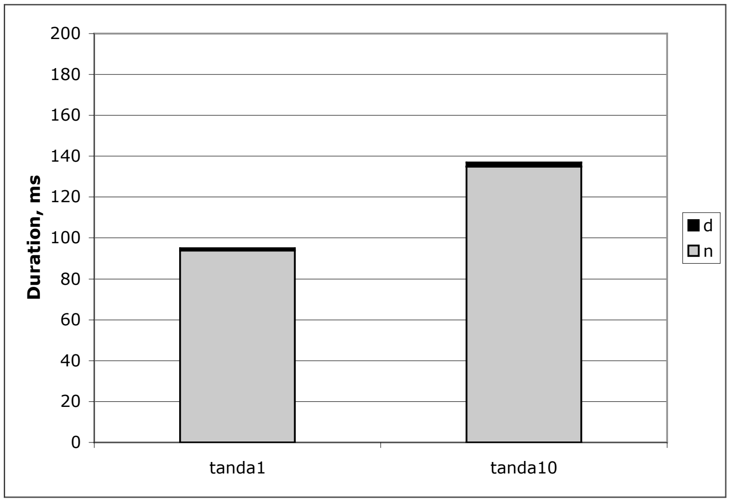

Figure 6.8: Manado Malay. Duration of nasal and oral portions of /nd/ in medial position for two repetitions of /tanda/ 'sign' by M5 (repetitions one and ten).

Although the same generalizations about nasal and oral components of NC sequences can be made across the languages, there are some slight differences between the languages. Manado Malay speakers tend to have the shortest oral portions in sequences (an average of 4 ms for alveolars and 5 ms for bilabials), while Tamambo speakers tend to have the longest (an average of 15 ms for alveolars and 23 ms for bilabials). Pamona and Erromangan speakers fall somewhere in between. These differences are not related to phonological structure, however. Speakers also show individual tendencies, with some always exhibiting a clear oral portion and others often having no identifiable oral portion.

6.2.1.1 Prenasalized stops or post-stopped nasals?

The fact that all voiced NC sequences tend to be primarily nasal, with only a brief oral portion, raises some interesting questions for other types of nasal-oral consonant sounds that have been identified, in particular post-stopped nasals. Post-stopped nasals (also referred to as "orally-released nasals", "post-ploded nasals", or "funny nasals"), have been reported in several dialects of Chinese (Chan 1987), as well as a handful of languages in Indonesia, including Sundanese (Robins 1957), Rejang (Coady and McGinn 1982), Acehnese (Durie 1985), and Gayo (Eades 2005). (See Blust 1997 for an overview of the Austronesian cases.) These segments are generally described as being fully nasal, except for a very brief oral release at the right edge, and are primarily characterized by a lack of nasalization on the following vowel.

Post-stopped nasals are typically represented by a raised stop following the nasal, as in /ŋ^{g}/ in the Acehnese word /ŋ^{g}ram/ 'angry', the compliment to the representation given to prenasalized stops. The assumption implicit in the differing representations, as well as in some descriptions of the sounds, is that post-stopped nasals differ from prenasalized stops in having a shorter oral portion. However, as seen in the data in chapter 4 and the beginning of the present section 6.2.1, prenasalized stops also have an extremely brief oral portion, if any oral portion at all, and are primarily characterized by a lack of nasalization on the following vowel. Given these facts of phonetic timing, prenasalized stops would also more accurately be represented as N^C.

Before proceeding with the question of whether or not post-stopped nasals are distinct from prenasalized stops, it is important to address the issue of unary vs. cluster status. Although post-stopped nasals are often assumed to be unary, the same question can be asked about their phonological status as is asked about other NC sequences: is there clear evidence for a unary analysis? This issue has not been investigated for many of the cases cited above. For the present point regarding nasal-oral timing, this issue is in fact somewhat peripheral, because the phonetic facts of nasal-oral timing hold regardless of phonological status. In the following discussion, I will assume that post-stopped nasals are unary, but the important issue of their status should be addressed in analyses of individual cases (and is discussed more generally in section 6.5.3).

Are prenasalized stops and post-stopped nasals distinct? Based upon the general descriptions of the phonetic character of post-stopped nasals in the literature, and the phonetic data on prenasalized stops (and NC clusters) in this thesis, there do not appear to be any systematic differences between the two sound-types. However, some differences have been suggested. Chan and Ren (1987) investigate the post-stopped nasals in two Chinese dialects—Zhongshan and Kaiping—where the sounds are allophones of plain nasals. They compare the post-stopped nasals with NC sequences assumed to be prenasalized stops in Malagasy and find that post-stopped nasals have a weaker nasal murmur and are shorter in duration. While these results are intriguing, they are quite preliminary, based upon only one primary speaker each of the Chinese dialects and a sample of Malagasy from Berkeley's *Sounds of the World's Languages* database (and therefore different recording conditions). One drawback of the study is that there are no language-internal comparisons of these sounds with simple nasals or other segments. Therefore, the nasal murmur and duration characteristics attributed to the different NC-types may instead reflect language-specific phonetic properties of nasals in each language rather than be representative of post-stopped nasals and prenasalized stops. In addition, the unary status of NC sequences in Malagasy is questionable (and I would venture the sequences are actually clusters), which could further explain the duration differences. The authors also compare the Malagasy sequences to samples of other prenasalized stops in the database and find great phonetic variability. They therefore conclude that it is not yet possible to determine whether or not post-stopped nasals differ from prenasalized stops, not without a better understanding of the phonetic characteristics of prenasalized stops, and I fully concur.

Maddieson and Ladefoged (1993) conduct a small study of the post-stopped nasals in Acehnese (where the sounds are in contrast with plain nasals, unlike those in Chinese). They find that the velum is not fully lowered in the production of a post-stopped nasal as compared to a plain nasal (based upon higher intraoral pressure and lower volume of nasal airflow in a postploded nasal). Given that this comparison is between a post-stopped nasal and a plain nasal, however, rather than a prenasalized stop, it is not clear if the lesser amount of nasal airflow, as well as the abrupt oral transition that it is said to facilitate, could also be characteristic of a prenasalized stop. The authors also argue that the post-stopped nasals do not have an oral closure while prenasalized stops do—based upon a comparison with a prenasalized token from Sukuma (where an increase in intraoral pressure during the NC closure signifies the oral closure).[3] However, Chan and Ren found the presence or absence of an oral closure in post-stopped nasals to be inconsistent in their own study, as the two Chinese dialects differed in this regard, and Kaiping had oral closures similar to those found in Malagasy. Ultimately, Maddieson and Ladefoged acknowledge that the two sound-types "shade into each other" (283).

The Chinese and Acehnese post-stopped data are best viewed as preliminary. It is possible that additional studies will reveal the observations identified above to be more widely representative of the sounds in question. However, at this point, it is not known whether the post-stopped nasals always exhibit these characteristics, while at the same time, it is clear from the data in this thesis that prenasalized stops sometimes *do* exhibit these characteristics. When it comes to the most consistent characteristic of post-stopped nasals—strong nasal airflow throughout the duration and a very brief oral component—the prenasalized stops in this study look identical acoustically. A next step would be to consider not only acoustic data, but also intraoral pressure data for more languages.

Of course, it is not only prenasalized stops and post-stopped nasals that exhibit these sorts of nasal airflow patterns. The data in this thesis reveal that voiced NC clusters are also composed almost entirely of nasal airflow with only a brief oral period, if any identifiable oral period at all. For example, in

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[3] The NC sequences in Sukuma are actually clusters, as discussed in chapter 3, section 3.1.2, although I would argue that the unary versus cluster status does not impact the relative nasal-oral timing in this regard.

the following waveform and spectrogram of the /nd/ cluster in the Manado Malay word /ta**nd**a/ ‘sign’ by M3, no oral closure can be identified. This pattern can also be observed in the airflow data in chapter 4, section 4.3.

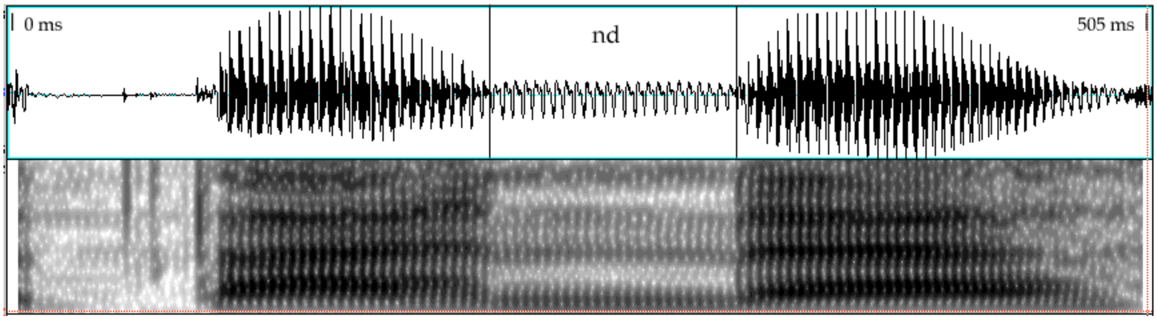

Figure 6.9: Manado Malay. Representative waveform and spectrogram of /tanda/ ‘sign’ by M3. Frequency on Y-axis is 0-5000 Hz.

The fact that these patterns of relative timing hold irrespective of phonological structure suggests a phonetic explanation. As discussed in chapter 4, section 4.4, an oral closure is apparently not necessary for the perception of these sequences (simply an oral release). In addition, it is arguably easier for the velum to remain open or to raise gradually than to precisely time a closure before the release, as discussed in chapter 1, section 1.4. This combination of perceptual and articulatory factors is likely the cause of the long nasal closures in these sequences. This topic is need of further study in a wider range of languages. Cohn and Riehl (2008, to be presented) are currently undertaking studies of this topic in additional languages, and will suggest in a forthcoming paper that prenasalized stops and post-stopped nasals are neither phonetically nor phonologically distinct.

6.2.2 NC̥ sequences

The NC̥ stop sequences, all of which constitute clusters, have three distinct components: a nasal closure, a voiceless oral closure, and a voiceless oral release (burst and aspiration). The following bar graph contains average durations of alveolar NC̥ sequences and corresponding plain nasals and stops in medial position, from one representative speaker of each of three languages (excluding Tamambo which has no NC̥ stop sequences).

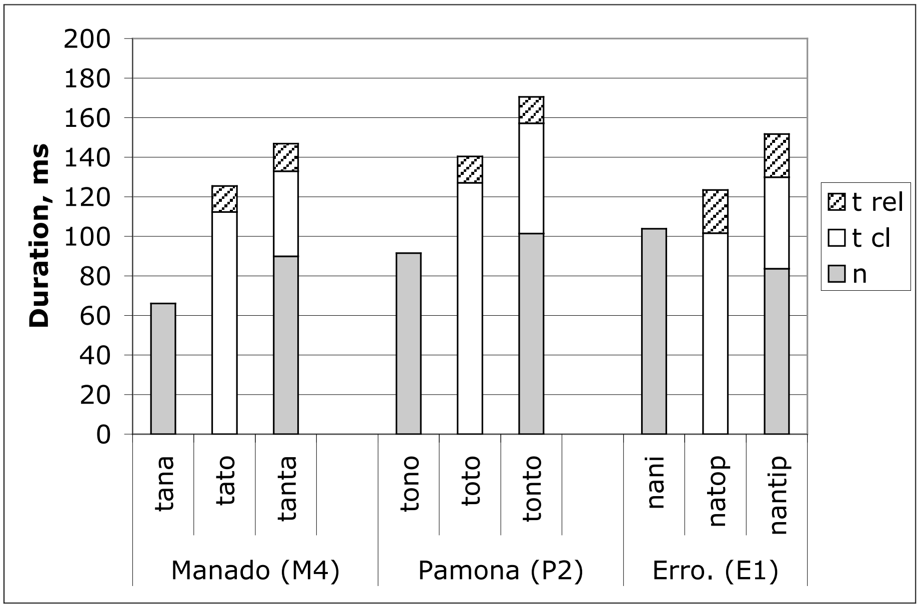

Figure 6.10: Average durations of component parts of /nt/ and corresponding plain segments in medial position, for one speaker each of Manado Malay, Pamona, and Erromangan, based upon data in chapter 5 (figures 5.17, 5.28, 5.42).

As seen in the figure, the duration of the nasal component of a sequence is on average longer than a plain nasal in both Pamona and Manado Malay, whereas in Erromangan, the nasal component of the sequence tends to be slightly shorter than a plain nasal. Regarding the duration of the oral closure, it is consistently shorter in a sequence than in a plain stop, although there is still always (and without exception) a substantial voiceless oral closure in the sequences.

The average duration of aspiration is remarkably stable whether it is occurring as a part of a plain stop or an NC̥ sequence, and despite the fact that the total duration of the oral portion is reduced in the case of the sequence. For example, Manado Malay speaker M4 has an average of 13 ms of aspiration in both the medial /t/ in /ta**t**o/ and /nt/ in /ta**nt**a/; Pamona speaker P1 has an average of 13 ms of aspiration in both the plain /t/ of /to**t**o/ and the /nt/ in /to**nt**o/; and Erromangan speaker E1 has an average of 22 ms of aspiration in both the /t/ in /na**t**op/ and /nt/ in /na**nt**ip/. In addition, there is very little intra-speaker variation across repetitions of a form. For example, the following figure includes two repetitions of /ta**t**o/ by M1. The duration of the medial /t/ in the first token has a closure of 116 ms followed by 16 ms of aspiration, while in the more slowly articulated second token, the same sound has a closure of 155 ms followed by 18 ms of aspiration, a difference of 30 ms between the closure durations but only two ms between the aspiration durations.

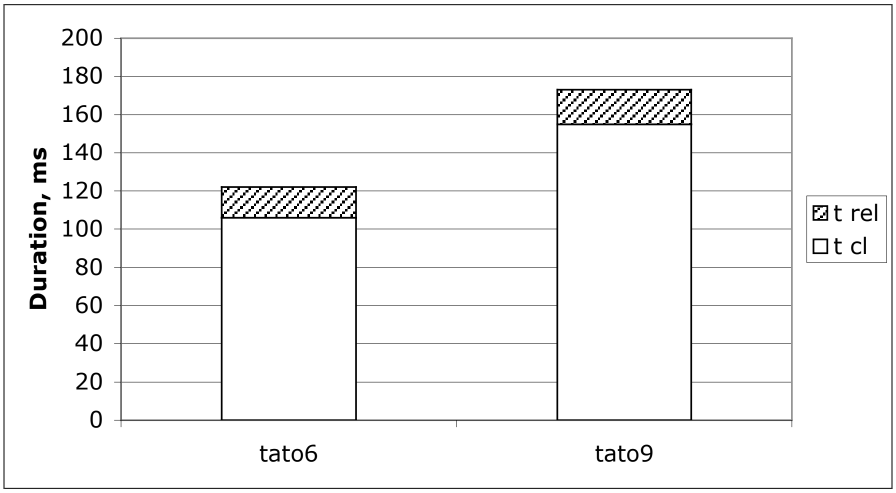

Figure 6.11: Manado Malay. Duration of closure and aspiration in /t/ in medial position for two repetitions of /ta**t**o/ ‘tattoo’ by M1 (repetitions six and nine).

The same relative patterns exhibited for the alveolars in medial position in this section are also found in initial position, as well as at the other places of articulation. Overall, average durations of aspiration range from about 10-20 ms across the speakers of each of the languages at the bilabial and alveolar places of articulation, with some speaker variation, and with a tendency for Tamambo and Erromangan speakers to have longer periods of aspiration, and for velars to have more aspiration than bilabials or alveolars. The implications of this data for representational issues are taken up in section 6.5.

6.2.3 NC Affricates

The NC affricate data presented in chapter 5 include unary segments (Tamambo) and clusters (Pamona and Manado Malay) with voiceless oral portions. These sequences are composed of a nasal closure, followed in most cases by a voiceless oral closure, and finally a voiceless fricated release. The NC affricates differ from the NC̬ and NC̥ stop sequences in exhibiting more variability in the realization of their oral phases. The following figure contains average durations of initial and medial alveopalatal NC affricate sequences, alongside plain alveopalatal affricates (where available), and alveolar nasals, from each of the three languages.

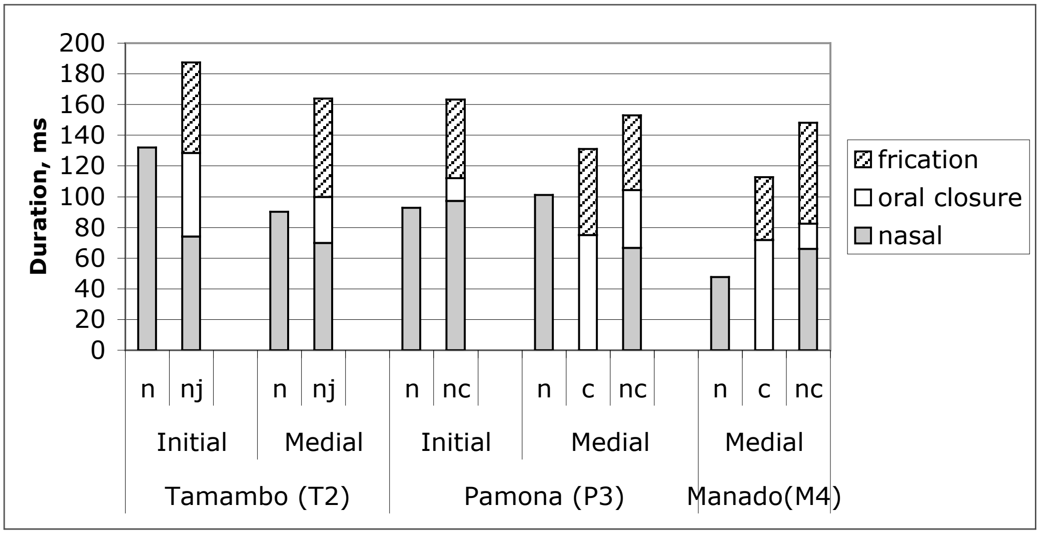

Figure 6.12: Average durations of component parts of alveopalatal affricates and alveolar nasals in initial and medial position, for one speaker each of Tamambo, Pamona, and Manado Malay, based upon data in chapter 5 (figures 5.12, 5.13, 5.23, 5.36, 5.37). [Note: “c” represents /tʃ/, “j “ represents /dʒ/.]

The comparison between the duration of a plain nasal and NC affricate sequence is likely not as informative in this case (as compared to the NÇ̬ and NÇ̥ stop sequences), given the mismatch in place of articulation: the plain nasals above are alveolar while the affricates are alveopalatal. In general, the nasal portion of the /ntʃ/ cluster in Manado Malay is a bit longer than a plain alveolar nasal, while unary /ⁿdʒ/ in Tamambo has a shorter nasal closure in the sequence. In Pamona, the results vary somewhat, with a tendency for a shorter nasal portion in the sequence when in initial position but not medial. Regarding the durations of the oral portions, the oral component is shortened when in a sequence, as compared to when occurring independently. However, a substantial portion of the total duration of the sequence is oral, roughly half, more than that seen in the NÇ̥ stop sequences, due to the presence of frication which is longer than aspiration.

The relative durations of the oral closure and release in the affricates exhibit variability in several ways, different from the NÇ̥ stop data. Considering first the plain affricates for comparison, Manado Malay speakers generally have longer oral closures than fricated releases. However, speakers vary in the duration of the release portion, from an average as small as 18 ms for M5 to as large as 41 ms for M4. For Pamona speakers, the fricated releases tend to be longer, comprising about half of the total duration of the segment, but again with much speaker variation, from a release duration as small on average as 48 ms for P1 and as large as 85 ms for P2. The observed inter-speaker variability is different from the voiceless stop data, where speakers show similar release durations to one another. Intra-speaker data are fairly steady for the affricates, although the values also vary more than in the case of aspiration in plain stops, especially for Pamona speakers.

Like aspiration, however, the release portion tends to have a certain average duration regardless of the total duration of the segment. The following figure contains two repetitions of /atʃe/, *proper name*, by Pamona speaker P5. In the first token displayed, the total duration is 190 ms, 68 ms of which is attributed to a release, while the total duration of the second token is 149 ms, 69 ms of which is attributed to release.

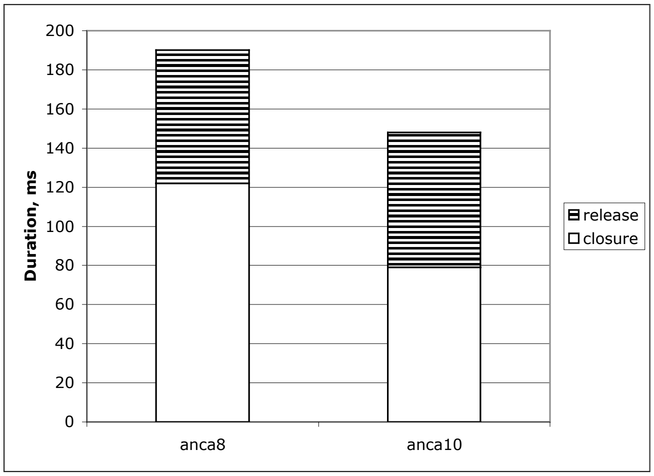

Figure 6.13: Pamona. Duration of oral closure and release in /tʃ/ in medial position in two repetitions (repetitions 8 and 10) of /atʃe/, a proper name, by P5. [Note "c" represents /tʃ/.]

Despite the durational equality of the fricated portions in this figure, however, it is important to recognize the variability in frication durations, as stated above. This speaker, for example, has a range in release durations from 62 to 84 ms; a few speakers have even greater ranges, and in some cases there does appear to be a slight tendency for release durations to increase with total duration.

The NC affricates differ in their patterns from the plain affricates, as well as the other NC sequences, and show notable inter-speaker variation. While most speakers do have a clear oral closure in these sequences, some have much more substantial closures than others, while other speakers often have no oral closure at all. For example, in figure 6.9 below, one speaker of each language has a small average oral closure and another a long average oral closure.

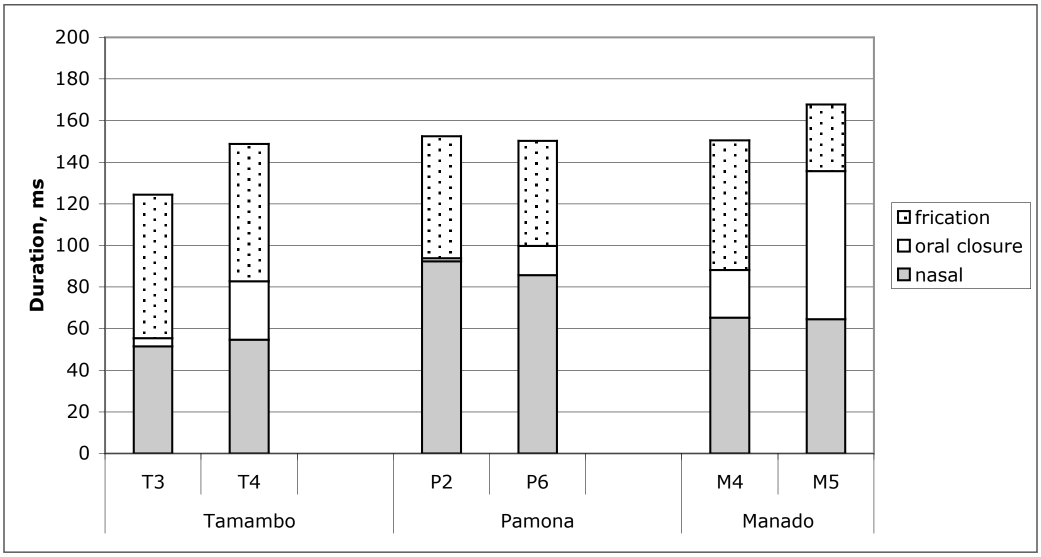

Figure 6.14: Average durations of component parts of NC affricates by two speakers each in Tamambo /ta$^{\text{n}}$dʒi/ ‘to sharpen’, Pamona /ntʃani/ ‘to know’, and Manado Malay /kuntʃi/ ‘key’, based upon data in chapter 5 (figures 5.13, 5.36, 5.23).

These data are very different from those seen for the NC̥ stop sequences, where all speakers had substantial oral closures, without exception.

While the closure in an NC̥ stop sequence is necessary, to lend the percept of a voiceless stop, as discussed in chapter 1, section 1.4, it is obvious from these data that a voiceless oral closure is not a necessary component of an NC̥ affricate. Instead, the perceptual load is carried by the relatively long period of high frequency frication.[4]

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[4] This difference may be the reason why NC̥ affricates and NC̥ stops are often treated differently in nasal substitution contexts, such as those discussed in chapter 1, section 1.3. In languages like Indonesian, where NC̥ stop sequences are reduced to homorganic plain nasals, as in [mə**n**urun] ‘to descend’ from /məŋ-**t**urun/, NC̥ affricates, like the voiced NC sequences, often remain unchanged, as in [mə**ntʃ**ari] ‘to look for’ from /məŋ**tʃ**ari/. (See Blust 2004 for discussion of this issue in additional languages.) NC̥ stop sequences are arguably altered due to the relative difficulty of producing the voiceless oral closure in this context, while the NC̥ affricates do not have the same articulatory burden.

Given the closure facts, and given that speakers exhibit fairly steady release durations in the case of plain affricates, as seen above, one might expect that the duration of the fricated release in NC affricates will be similar to that found in plain affricates, while the oral closure may be replaced in whole or in part by a nasal closure. Interestingly, however, the average duration of the release in the sequences is different than it is in plain affricates. Manado Malay speakers all have longer average releases in NC affricates, an average of 10-20 ms longer, while all Pamona speakers have shorter releases in NC affricates than in plain affricates, an average of 10-20 ms shorter, suggesting language-specific phonetic implementation.

The affricate data have implications for the representation of NC sequences. This topic will be taken up in section 6.5.1.

6.2.4 Conclusions- Duration of component parts

The relative durations of the component parts of the NC sequences do not relate to phonological structure. Interestingly, in the case of voiced NC sequences, an essentially identical pattern was seen across speakers and languages, whereby almost the entire duration is nasal, with only a brief oral component. Given these phonetic characteristics, I explored whether or not prenasalized stops differ from another proposed unary NC-type similarly described—post-stopped nasals—and suggested that they do not. In NC̥ stop sequences, speakers of all languages have substantial nasal closures and oral closures, followed by a period of aspiration which remains steady in duration regardless of the total duration of the obstruent portion. NC affricates differ from the aforementioned cases; while all speakers consistently have nasal closures and oral fricated releases, there is great variation in the length, or even the presence, of an oral closure.

6.3 Methodological conclusions

In this section, I briefly review some methodological issues raised in chapter 3 as they relate to the outcomes of the acoustic study. The importance of multiple speakers, multiple repetitions, and relative comparisons are addressed, as are the methods of analyzing and presenting the data.

First, the results confirm the importance of considering data from multiple speakers. In terms of total duration, although for the most part all of the speakers of a language in this study exhibited similar total duration patterns, sometimes a speaker of a unary language would have an unusually large N:NC ratio while a speaker of a cluster language would have an unusually small one. In a study that included only one or two speakers of each language, atypical data from a particular speaker could have greatly affected the overall results and even led to the opposite conclusions. In addition, having multiple speakers of each language made it possible to determine which relative nasal-oral timing patterns appear to be invariant across languages and which do not. For example, NC̥ stop sequences are always composed of three distinct phases—nasal closure, oral closure, and oral release, while NC̥ affricates appear to be variable in having a notable oral closure. If fewer speakers of each language had been considered, the variability in affricates may not have been observed, or the invariance in NC̥ stop sequences may not have been clear. Finally, recording multiple speakers of each language means that if a particular speaker's data are difficult to analyze for some reason, they can be eliminated from the study. For the present project, spectrograms of certain speakers were difficult to label. Given the large number of speakers and great importance of accurate labels for the duration results, however, I was able to exclude these speakers from the study, using data only from those speakers whose waveforms and spectrograms were straightforwardly interpretable. Even given the relatively large number of speakers initially recorded for this study, however, a lack of good data in certain areas yielded less conclusive results, as was the case for the velars, and yielded no data in others, as was the case for voiced NC affricates.

In addition to the importance of multiple speakers, the importance of multiple repetitions has also been illustrated. As can be seen in the box plots, the duration values of segments exhibit some variability for all speakers and have particularly large ranges for certain speakers. If fewer tokens were considered, it is possible, for example, that a speaker's unusually long unary NC token would be compared to his/her typically short plain nasal, and the incorrect conclusion that the unary NC sequences are the duration of two segments would be reached. In addition, having multiple repetitions means that tokens that are difficult to measure can be excluded from the data. For the present study, starting with at least ten repetitions by each speaker meant that if several repetitions were difficult to label, they could be eliminated to increase accuracy. In some cases, difficulties with a speaker's data meant a great reduction in the number of tokens and yielded less conclusive results—particularly where velars were concerned.

The data also highlight the importance of relative comparisons. As discussed in chapter 3, section 3.1.2, in a number of previous NC studies, the durations of segments are compared across languages, for example comparing the total duration of an NC in a unary language with an NC in a cluster language. Such comparisons are highly suspect, however. The only reliable comparisons across languages are relative ones that can be made based upon N:NC ratios in each language. In the present study, for example, a speaker of Tamambo may have a unary NC with a similar total duration to the NC cluster by a speaker of Manado Malay. Such data may lead one to conclude that there is no unary-cluster difference. However, a look at the durations of plain nasals in each language, and how they relate to the durations of the NC sequences, reveals that the sequences have very different patterns in the two cases: the unary NCs are the duration of plain nasals and the cluster NCs are much greater in duration.

Related to the importance of having multiple speakers and repetitions is analyzing and displaying data in such a way that all of this information is available. Presenting the data from each individual speaker, rather than presenting only averages across speakers, yields more accurate results. For example, in the case of bilabials, for some speakers the N:NC ratio for clusters in Manado Malay is not as great as it is at the other places of articulation. If averages across the speakers had been displayed, rather than data from each individual speaker, it would have revealed a smaller overall N:NC ratio at this place of articulation for Manado Malay, which may have given the impression that each speaker had a smaller ratio in this case, rather than that some speakers had a large ratio, while others had a very small one. By the same token, displaying all of the data from each speaker in box plots, rather than presenting only averages across the repetitions, had the advantage of revealing large variation in some cases.

A final point relates to statistical significance in comparisons of duration. As discussed in chapter 3, section 3.2.5.1, whether or not two groups are significantly different is not necessarily informative in discussing how phonological units are phonetically realized. Significant differences proved to be only part of the story in analyzing the data in the present study. In all cases where NC clusters are claimed to be substantially longer than plain nasals, this difference is highly significant. However, in cases where unary NCs are said to be about the same length as plain nasals, there are sometimes small differences in duration between the two that are also significant. Importantly, on the whole these differences in the unary languages, Tamambo and Erromangan, are much smaller than they are in the cluster languages, Pamona and Manado Malay. Therefore, reflecting on the magnitude of these differences and examining the range of data in each case to determine how much overlap in categories is present, proved to be much more informative than significant differences alone.

6.4 Phonetically-motivated phonological gaps

In chapter 2, section 2.1, I presented a classification of NC pattern-types. Of 16 possible combinations of NC clusters and unary segments with voiced and voiceless oral components (including one type with no NCs), I argued that only six are occurring. The ten non-occurring patterns were attributed to two main gaps: the lack of contrasting unary and clusters NCs, and the lack of prenasalized voiceless stops. In this section, I offer reasons for these gaps, based upon the phonetic data presented in chapters 4 and 5.

6.4.1 No contrast between unary and cluster NCs

If unary and cluster NCs are two distinct phonological entities, as argued in chapter 1 and fairly widely accepted, then why do they not contrast in any language? This absence of contrast is evidenced by very few reported cases in the literature, and a reinterpretation of the few cases that have been proposed—in particular Sinhala and Fula, as discussed in chapter 2 under "Type D:3a". As discussed, the only documented cases all share an important property of being languages with a singleton-terminate contrast (a point to which I will return to shortly.) An assumption often implicit in discussions of the lack of contrast is that the two phonologically distinct entities do not systematically differ phonetically, and therefore a contrast in a single language is not possible. However, I have shown in this thesis that there is in fact a phonetic difference between unary and cluster NC sequences. The question of why the two types do not contrast is therefore even more puzzling: If unary and cluster NCs are phonologically and phonetically distinct, then why do they not contrast? I argue that it is the nature of the phonetic difference that explains the phonological gap.

The data in chapter 5 illustrate that unary and cluster NCs differ in terms of total duration: NC clusters are substantially longer than plain nasals while unary NCs are about the same duration as plain nasals. Importantly, however, the two NC-types do not appear to differ in any other way: the degree of nasalization in a preceding vowel and the duration of a preceding vowel—two other factors systematically studied in this thesis—do not vary in accordance with the NC-type. At the same time, an interesting similarity between the two types is observed: both unary and cluster voiced NCs are composed almost entirely of nasal airflow, ending in a brief oral release. The sequence-types differ, therefore, only in the duration of the nasal closure, as schematized below:

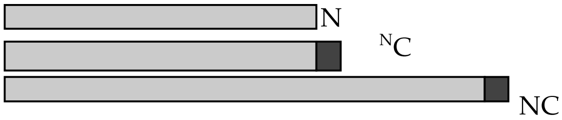

Figure 6.15: Schematization of relative duration differences between a plain nasal, prenasalized stop, and nasal-obstruent cluster; light gray= nasal, dark gray= oral

The difference in total duration between unary and cluster NCs, and the similarity in nasal-oral composition, together account for the lack of phonological contrast.

The phonetic difference between a unary and cluster NC is a difference in length of the nasal closure. This difference looks very much like that observed between a singleton and geminate nasal. I propose, therefore, that only a language with phonemic length—one that contrasts singleton and geminate consonants—would be able to maintain a contrast between a unary and cluster NC. Not surprisingly, the only languages that have been reported to have a unary-cluster NC contrast—Sinhala, Fula, and Selayarese—are languages that contrast singletons and geminates. As discussed in chapter 2, section 2.1, for the first two cases, the purported unary-cluster NC contrast has already been reanalyzed as a singleton-geminate contrast (Ladefoged and Maddieson 1986, Maddieson and Ladefoged 1993, Letterman 1997). Furthermore, phonological alternations between "unary" and "cluster" NCs in these languages pattern just like singleton-geminate alternations. The NC contrast in these languages, therefore, is better characterized as a singleton-geminate NC contrast, rather than a unary-cluster NC contrast.[5] I predict that no language without phonemic length will be found that contrasts the two NC-types.

Preliminary phonetic data by Ladefoged and Maddieson (1986) as well as Letterman (1997) support the analysis that the NC contrast is actually a singleton-geminate contrast. Ladefoged and Maddieson find that, for two speakers, the "prenasalized stops" are about 100 ms, while the "clusters" are twice as long for one speaker and almost three times as long for another, and further that the "additional duration is added in the nasal portion, resulting in a nasal of comparable duration to a geminate nasal" (43). Similarly, Letterman finds that the "mean duration of geminate [nn]/[mm] (183 msec) was virtually identical with the mean duration of so-called nasal+stop sequences [nd]/[mb] (182 msec)" and further states that "these sequences are durationally equivalent to geminates because they are geminates" (216).[6]

To summarize, the lack of phonological contrast between unary and cluster NC sequences has a phonetic basis. The phonetic difference between the two NC-types is—significantly and solely—the length of the nasal closure. Such a difference could only be used contrastively in a language with

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[5] Whether or not the contrast is one between a singleton and geminate prenasalized stop, or a singleton and geminate nasal followed by an oral stop, is a separate matter, as discussed in chapter 2, section 2.1. This issue may be informed, however, with additional phonetic data, in particular the duration of plain nasals as compared to the NC sequences.

[6] Note that the difference in "unary vs. cluster" NC duration in these studies is much larger than that found between the plain nasals and NC clusters in my data, which may be viewed as additional evidence that the difference in Sinhala is one of singletons versus geminates.

In addition, Letterman provides duration data illustrating that the NC "clusters" are longer than regular nasal codas (182 vs. 106 msec), as evidence that the former are geminates (rather than simply clusters with the nasal in coda). It is difficult to know how to interpret the data, however, since the nasal in a heterosyllabified NC cluster (such as Manado Malay) also appears longer than expected (likely longer than a nasal coda that does not precede a homorganic obstruent) due to the phonetic realization of these sequences.

phonemic length, where it is better characterized as a singleton-geminate contrast than a unary-cluster contrast.

6.4.2 No prenasalized voiceless stops

I argued in chapter 2, section 2.1 that unary NC̥ stops do not occur, given the absence of clear cases attested in the literature. I now turn to the question of why this should be the case, and find some explanation in the phonetic character of these sequences. In contemplating why prenasalized voiceless stops do not develop, it is useful to think about why and how prenasalized voiced stops do develop. (I focus here on phonological prenasalized stops, not those that arise as allophones of plain nasals in nasal harmony systems, which are briefly addressed in section 6.5.3.)

As discussed in chapter 1, section 1.4, voicing is difficult to maintain during a stop closure, because the vocal folds stop vibrating once the supraglottal pressure exceeds subglotal pressure. The escape of air through the nasal cavity reduces supraglottal pressure and facilitates the vibration of vocal folds, leading Stevens et al. (1986) and others to discuss nasalization as an enhancement to voicing. The result is that the voiced stop series in some languages is fully voiced as well as slightly nasalized, and is maximally distinct from a voiceless stop series.

Prenasalization is sometimes said to have developed on the series of voiced stops in a language as an enhancement of voicing. Although there is little clear documentation of this development in most cases, it is certainly a strong possibility. Such cases have been cited for Mixtec (Iverson and Salmons 1996) and several dialects of Japanese (Nasukawa 2005), and are often noted in languages of Melanesia and Papua. Flemming (1995) offers an Optimality Theoretic account of the phenomenon. When voiced NC sequences arise in this manner, it is hardly surprising that they are generally accepted as unary segments. As discussed in chapter 1, section 1.3, the strongest piece of evidence for unary segmenthood— inseparability—is present, given that all voiced stops now have a nasal component.

Ohala and Ohala (1991) describe another environment where NC sequences may develop from what were plain voiced stops: formation of an intrusive nasal when a nasalized vowel precedes. They make such a case for Modern Hindi, claiming that intrusive nasals formed before voiced stops, but not voiceless, when a nasalized vowel preceded, due to nasal airflow continuing after the formation of the voiced stop, causing the beginning of the stop to be nasalized. (This did not happen before voiceless stops, where the nasal airflow would "undercut their stop or voiceless character" (213); see chapter 1, section 1.4.) The epenthetic nasal element in this case became phonologized and lengthened to the duration of a lexical nasal, and the NC sequences now form clusters. The cluster account is understandable in Hindi, where the sequences are separable, with plain voiced stops occurring after oral segments and initially.

Prenasalization as an accompaniment to voicing, in both of the above contexts, obviously does not occur with voiceless stops. The phonetic motivation is simply not there; in fact, prenasalization can be viewed as antagonistic to the maintenance of voicelessness. Not only does this mean that NC̥ sequences will not form in these ways, it also means that NC̥ sequences will never fall into the "inseparable category", and therefore that the best evidence for unary segmenthood is not available. As discussed in chapter 2, section 2.1, all languages have at least one series of plain stops, which is characteristically voiceless in the absence of a contrast. If unary NC̥ sequences do not arise by altering this series of stops (the way that unary NC̬ sequences may through voicing enhancement of the voiced stops), then they can only be added to the inventory as a separate series, alongside the plain voiceless stops, and they will therefore always be "separable".

Another way that prenasalized voiced stops may develop is when an NC cluster is reanalyzed as a unary segment. This phenomenon is frequently noted in forms that were at one time morphologically complex, for example, where a nasal prefix attached to a consonant-initial stem, but where the morpheme is reanalyzed as part of the stem, leaving an NC sequence that then forms a unary segment. It is often argued that unary segments form in this manner synchronically as well, despite being underlying clusters. A large number of African languages have been cited as having prenasalized segments that arise in this manner. Herbert (1986) reviews many of these cases and although I would disagree with the unary analyses for some, the point to be made about the absence of unary NC̥ segments still stands. Oftentimes in such cases, the NC̥ sequences follow a different path, with the nasal portion becoming syllabic or deleting, or the stop portion voicing, again suggesting that formation of a unary NC̥ segment is not possible.

The question is why this should not be possible. When NC̬ and NC̥ sequences occur in the same environment, or arise through the same means, yet ultimately meet different ends, clearly it is due to the differing voice properties of the obstruent. The difference between an NC̬ and NC̥ sequence is that in the first case, the two elements share the same voicing property, with both the nasal and obstruent being voiced, while in the second they clash, with the nasal being voiced but the obstruent voiceless. As sequences of nasals and voiceless stops do occur quite commonly, in the form of clusters, it is not the case that these two elements are necessarily incompatible (although they are clearly less uniform and stable than voiced NC sequences). Rather, there is something problematic about the voice properties being different while residing in the same segment. I will argue in section 6.5 that a single segment cannot bear two different voice specifications and that this inability is captured in the proposed representations. However, the reasons why this should hold for NC̥ sequences must still be explained. I propose that part of the explanation may be related to length.

As seen in chapters 4 and 5, NC̬ and NC̥ sequences do not differ phonetically simply in whether or not the vocal folds vibrate during the oral portion. While NC̬ sequences are composed of a nasal closure followed by a very brief oral portion, NC̥ sequences have three parts—a nasal closure, oral closure, and oral release. The added required element—a clear oral closure—is arguably necessary to lend the percept of a voiceless stop, as discussed in chapter 1, section 1.4. The consequence is that NC̥ sequences are quite long, much longer than single segments. The fact that NC̥ sequences will always have a total duration substantially longer than a single segment may be a factor in them consistently patterning as clusters. There are other cases where a phone, simply by virtue of being long, patterns as two segments. Palatals, which are intrinsically long, pattern like geminates in Italian rather than single segments (Chiercia 1986, Burzio 1989, Davis 1999). NC̬ sequences, on the other hand, may be the duration of a single segment, which contributes to the ease with which they can be accepted as single segments.

Length cannot be the entire story, however. After all, the unary NC affricates in Tamambo are much longer than single segments. (I return to the issue of their voiceless oral portions below.) Rather, there seems to a confluence of factors that prevents NC̥ stops from being possible unary segments. While the NC affricates in Tamambo are long, they also fall into the inseparable category, and this strong piece of evidence for unary segmenthood appears to outweigh the length properties. NC̥ stop sequences, however, are always separable, and therefore they can always be analyzed as separate segments. Speakers need clear evidence that a sequence of these individual elements has unary status. While NC̬ sequences, with the duration and voicing specification of a single segment, can function as unary, NC̥ sequences, with their greater length and conflicting voice properties, are apparently too unlike a single segment to be interpreted as one.

If NC̥ stop sequences are not possible single segments, then why are the NC affricates in Tamambo, which have phonetically voiceless oral portions, acceptable as unary? As discussed in chapter 2, section 2.2.1, for the wider Tamambo-speaking community, the sound in question is actually a prenasalized voiced palatal stop (Jauncey 1997, Riehl and Jauncey 2005) which often has a fricated release as in an affricate. The young urban speakers, however, such as those recorded for this study, consistently devoice this fricated release. There are likely phonetic motivations for this devoicing. As discussed in chapter 5, section 5.2.3, frication is difficult to produce when the vocal folds are vibrating, as they impede the high volume of airflow through the glottis that is needed to produce the turbulence (Johnson 1997). Thus the frication, to be most efficient, is voiceless, and this in turn leads to devoicing of the oral closure. In the case of prenasalized stops, there is no similar phonetic motivation for devoicing the oral portion, as the sequences are easier to produce when voiced. The oral portion of the prenasalized palatal stop in Tamambo appears to be undergoing a change from a voiced stop to a voiceless affricate. The increased length that comes with these new phonetic attributes may be a factor in this unary NC segment becoming an NC cluster over time.

In the following section, I argue that unary NC sequences have a single root node and therefore a single laryngeal node and voice specification. Prenasalized voiceless stops, with conflicting voicing values, are therefore not possible as phonological representations. Unary NC̥ sequences with phonetically devoiced oral portions, such as the affricates in Tamambo, can be accommodated, as long as the oral portion does not need to be phonologically specified as voiceless.

6.5 Representations of NC sequences

6.5.1 Phonological representations

In chapter 1, section 1.5, I introduced the different NC representations that have been proposed and their predictions. Now, given the data presented in this thesis, I return to this topic and offer representations that capture both the phonological patterns and phonetic timing observed. An important aspect of this discussion is the need to represent both segmental and prosodic structure. Where the previous interest in NC structure fell primarily on segmental structure (in feature geometric models, for example), and the more recent interest appears to fall primarily on prosodic structure (in moraic models, for example), I argue that, in order to capture the phonological patterns and phonetic data presented in this thesis, both aspects are crucial.

Figure 6.16 contains the proposed representations. Prenasalized stops, tautosyllabic NC clusters, and heterosyllabic NC clusters are represented, distinguished by voicing specification of the obstruent. Since the internal structure of the root nodes (such as where [nasal] and the laryngeal node reside) is not critical to this issue, simplified and abbreviated structures are included below the level of the root node. [nasal] is represented as bivalent, as this is necessary for the sequences with a single root node. [voice] is also represented as bivalent here, although its valency status has no direct bearing on these representations.

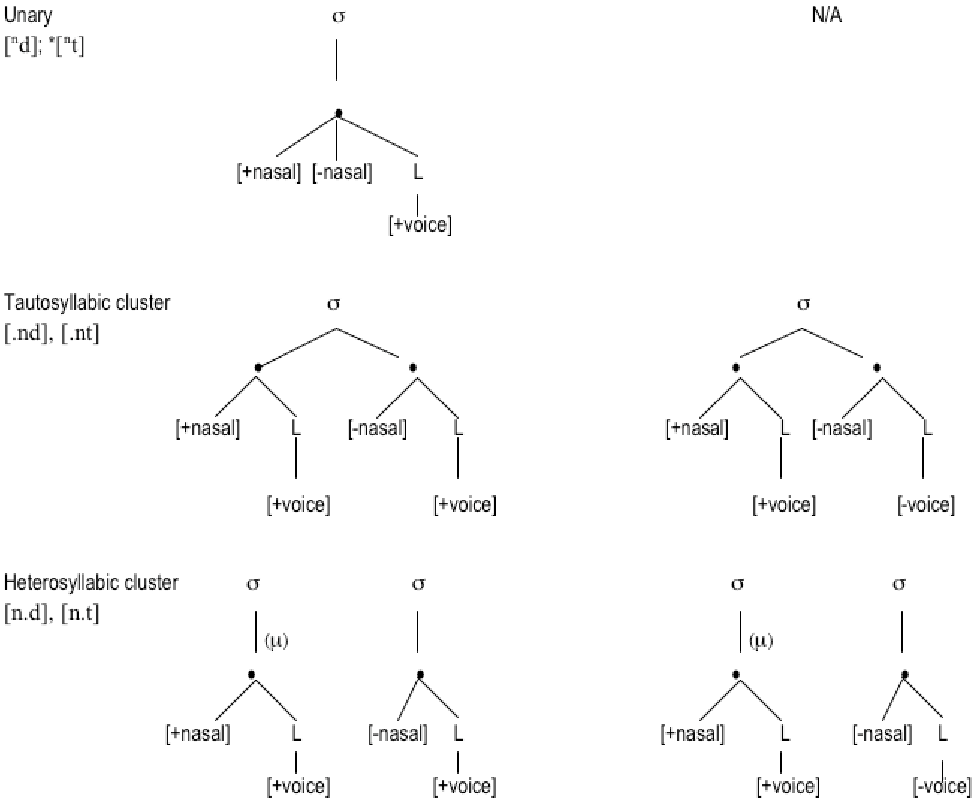

Figure 6.16: Proposed NC representations

As seen above, unary NC sequences are represented as a single root node attached to a single syllable, with two different specifications for the feature [nasal], and a single laryngeal node with a [+voice] specification. Prenasalized voiced stops are possible, whereas prenasalized voiceless stops are not, given that a single laryngeal node is widely assumed to be unable to bear two different [voice] specifications. Tautosyllabic clusters are represented by two root nodes associated with a single syllable; the clear generalization is that with two different laryngeal nodes, two different voice specifications are possible. Heterosyllabic clusters are represented with two root nodes, each associated with a different syllable. Again, structures with both voiced and voiceless obstruents are possible, given the separate laryngeal nodes. Coda nasals in the heterosyllabic structures may or may not be linked to a mora. Below, I argue that these representations are able to account for the range of observed phonological patterns, as well as the facts of phonetic timing.

As discussed in chapter 1, section 1.5, past proposals for the representation of prenasalized stops fall roughly into two categories—those that argue for a single root node (Sagey 1986, van de Weijer 1996) and those that argue for two root nodes (Clements 1987, Piggot 1988, Rosenthall 1988, Trigo 1993). Motivations for the different approaches are reviewed in that chapter and are also presented by Clements and Hume (1995). (Steriade's 1993 two-root node proposal, which differs in substance, will be discussed separately below.)

The data in this thesis support a single-root node analysis for prenasalized stops, for two reasons. First, a single root node predicts a restricted set of possible unary NC segments. In chapter 2, section 2.1, I argued that the nasal and oral portions of a unary NC sequence must agree in voicing (specifically that prenasalized voiceless segments—where the nasal portion is voiced and the obstruent portion voiceless—do not exist). A single-root node analysis, which contains only one laryngeal node and therefore allows for only one voicing specification, restricts the inventory of unary NC segments to those where the nasal and oral portions agree in voicing—precisely the desired outcome if this claim is correct.[7] Note that the prenasalized affricates in Tamambo can be captured by this representation given that the obstruent portion, although phonetically voiceless, does not contrast for voicing and may therefore may be phonologically specified with a [+voice] feature. That the obstruent devoices in this language is argued to be purely phonetic (as discussed in chapter 5, section 5.2.3). The prediction is that prenasalized obstruents cannot contrast for voicing in any language. Past proposals for a two-root node analysis have used the restrictiveness of a single root node as an argument *against* such representations, based upon claims in the literature that a wide variety of unary NC-types, including those with voiceless obstruents, exists. With the revised and more restrictive set of types presented in this thesis, however, in fact it is the single-root node structure that makes the correct predictions.

Second, a single-root node structure captures the facts of phonetic timing. The data in this thesis reveal that unary NC segments have the timing of a single segment, while both heterosyllabic and tautosyllabic NC clusters have the timing of two segments. As discussed in chapter 1, section 1.5, these facts cannot be captured adequately by the two-root node models in a grammar that assumes moraic theory. In the absence of timing tiers, both root

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[7] This includes prenasalized stops where both portions are voiceless, mentioned in footnote 4, chapter 1.

nodes of a prenasalized stop in onset position would attach directly to the syllable, making them indistinguishable from an onset cluster. Given the data in chapter 5 that reveal that tautosyllabic NC clusters are longer than prenasalized stops, such a model is not adequate. Rather, unary NC segments must have only a single root node, while clusters must have two. As mentioned in chapter 1, section 1.5, Maddieson and Ladefoged (1993) posit the same structures for the onset NC clusters in Luganda and the prenasalized stops in Fijian—two nodes attaching directly to the syllable onset. Their phonetic studies suggest that the Fijian unary NCs are the length of a single segment while the Luganda clusters are longer, and conclude that the phonological status of the NC therefore does not relate to duration. However, if the difference between these languages is modeled as proposed here, assigning one root node to Fijian and two to Luganda, the phonetic facts are accurately captured.

The similarities and differences between tautosyllabic and heterosyllabic NC clusters are easily accounted for with the proposed representations. The two root nodes in a tautosyllabic cluster link to the same syllable, while the two nodes in a heterosyllabic cluster link to two different syllables. In a language where the nasal in a heterosyllabic cluster is weight-bearing, this is easily captured through its link to a mora; in a language without weight-bearing coda nasals, the nasal node simply links directly to the syllable. (See Broselow, Chen, and Huffman 1997 for a fuller discussion of issues relating to the moraic structure of codas and phonetic timing, also Ham 1998 for similar discussion of geminates.) These representations correctly predict that in languages where the coda nasal is not weight-bearing, which is the case for the languages studied in this thesis, the durations of the heterosyllabic and tautosyllabic clusters will be roughly the same. In a language where the coda nasal is weight-bearing, the representations predict that a heterosyllabic NC cluster will be longer in duration than a tautosyllabic NC cluster, a prediction in need of verification with phonetic data. Further, these representations correctly predict that both tautosyllabic and heterosyllabic NC clusters can have either voiced or voiceless obstruents, as opposed to prenasalized stops where the nasal and obstruent must agree in voicing.

Given these basic structures, various other relationships or linkings between segmental and prosodic structure are possible. For example, a segment may be ambisyllabic. Maddieson and Ladefoged (1993) propose such a structure for Sukuma, where a moraic coda nasal undergoes a relinking, attaching to a following onset as well as sharing its mora with the preceding vowel. Without delving into all of the logical possibilities here, I will simply state that the ability to represent more complex relationships does exist in this model and importantly, that those structures will carry with them implications for phonetic timing. One of these possibilities, discussed in chapter 2, section 2.1, is that of a geminate prenasalized stop. Letterman (1997) proposes that the NC sequences in Sinhala are unary segments that undergo gemination through attachment to a preceding mora. Such a structure is straightforwardly represented as follows in figure 6.17 (essentially the representation proposed by Letterman).

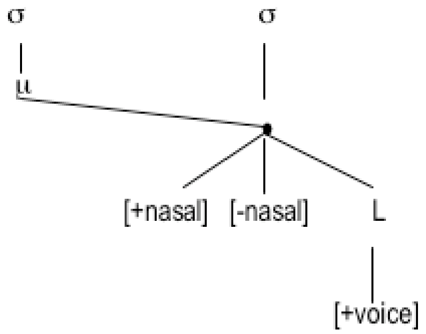

Figure 6.17: Representation of geminate prenasalized stop

6.5.1.1 Implications of phonetic data for the aperture node model

Steriade's (1993, 1994) aperture model also assigns two root nodes to NC sequences, but it differs markedly from standard feature geometric models. As discussed in chapter 1, section 1.5, in the aperture model, plain stops and affricates have two A-positions (a closure and a release), while other segments have only one (a closure *or* a release). Nasal contours are restricted to segments with two A positions, meaning only stops and affricates can be prenasalized. The following figure illustrates the representation of NC stops and affricates in this model, where [nasal] links to the closure, while the release remains oral.

(a) [nas]
|
A_0A_{max}
NC stop

(b) [nas]
|
A_0A_{fric}
NC affricate

Figure 6.18: Aperture node representations of NC stops and NC affricates by Steriade (1993).

As far as I understand, in this model, all onset NC sequences are treated the same. Any tautosyllabic homorganic NC sequence—whether an underlying unary segment or cluster—is a “single” segment, with a nasal closure and oral release (due to meeting the requirements for derived single segmenthood in this model—including having a single place node and otherwise compatible features, see Steriade 1993, p. 216). Ultimately, this model fails to account for the total duration facts of the data presented in this thesis, since cluster and unary NCs exhibit duration differences based upon whether or not they form one or two segments. However, it makes certain predictions about phonetic timing within NC sequences that in some cases are borne out by the data and worth exploring further.

Voiced NC stop sequences are given representation (a). Such a representation implies that these sounds are produced with a nasal closure followed by an oral release, without an oral closure. The data in this thesis are very consistent with such a representation. Overwhelmingly, both prenasalized stops and NC̬ clusters are composed of only these two phases, as discussed in section 6.2.1. Even though Steriade predicts variation in realization of the closure (such as an oral closure in some cases resulting from the raising of the velum before the release—unproblematic given that sounds do not contrast based upon the relative nasal-oral closure durations), in fact the data in this thesis illustrate that an oral closure is negligible in these sequences. Their characterization, therefore, as nasal closures followed by oral releases, seems a fair one in terms of representation.

NC̥ sequences present an interesting case. I assume that in the aperture model they are represented like the NC̬ sequences, differing only in the voicing specification of the release. This assumption is based upon the fact that Steriade includes NC̥ examples throughout her (1993) discussion (mostly affricates), and that she never explicitly states that NC̥ sequences have a different representation from NC̬ sequences. If this assumption is correct, then the representation implies that these sounds should be produced with a nasal closure and voiceless oral release. However, the data in this thesis reveal that all NC̥ stop sequences are produced with three clear periods: a nasal closure, an oral closure, and an oral release, as discussed in section 6.2.3. Although Steriade expects some variation in the realization of closures (as with the NC̬ sequences), NC̥ stop sequences are different from the other sequence-types in this regard. NC̥ stop sequences always, without exception across the languages, speakers, and repetitions in this study, have a substantial oral closure, unlike NC̬ sequences which have negligible oral closures, or NC affricates which do not consistently have oral closures. Further, as discussed in chapter 1, section 1.4, this closure is arguably necessary to lend the percept of a voiceless stop, and therefore it is a crucial aspect of an NC̥ sequence's character, and one that should be captured in the representation. The aperture model therefore does not correctly capture the facts of NC̥ sequences.[8]

Another interpretation of the model is possible, however. One of the criteria for an articulatory sequence to be a single segment, under the aperture model, is that the featural components are compatible—including the laryngeal features. Given the mismatch in voicing between the nasal and oral parts of a NC̥ sequence, one could argue that they cannot be represented by only two A positions—a single closure and release. (In fact, many of the NC̥

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[8] One might argue that cases of unary NC̥ sequences will be found that do not have an oral closure. I predict this will not happen. In any case, under the aperture model, all tautosyllabic sequences would be "unary".

cases in the 1993 article involve nasal loss or postnasal voicing, arguably motivated by the inability of the nasal and voiceless oral portions to coalesce, while the sequences discussed in the 1994 article have phonetically voiced oral portions.) One could argue that these sequences cannot be represented by two A positions—nasal closure and oral release (CR)—but must be a series of two segments and thus four aperture positions—closure and release for the nasal, closure and release for the stop (CRCR). Given that consonants are often unreleased before other consonants, the release on the nasal may delete, leaving three positions (CCR). The result would be that only NC̥ clusters would be possible—not unary NC̥ segments—a positive outcome in light of my claims against the existence of prenasalized voiceless stops.

NC affricates are given the representation (b) in figure 6.18. This representation implies that these sounds are produced with a nasal closure followed by an oral fricated release, with no oral closure. The data in this study reveal that most speakers actually have three distinct periods in these sounds: a nasal closure, an oral closure, and an oral release, as discussed in section 6.2.3. Although the fact that most speakers do maintain an oral closure is potentially problematic for this account, some speakers often *do not* have an oral closure, as illustrated for a speaker of each of the languages in chapter 5. In addition, general observation of the voiced NC affricates, for which data are not included in the thesis, reveals that the voiced sequences are even less likely to have an oral closure. This variation in the realization of closures in affricates is not observed with the NC̬ or NC̥ stops. Assuming Steriade's claim that NC fricatives and affricates do not contrast in any language holds true (and therefore that there is no NC affricate that *must* have an oral closure in order to maintain a contrast with a fricative), then the phonetic data in this thesis are consistent with the aperture node representation.

The primary failure of the aperture model, given the data in this thesis, is that both unary NC sequences and NC onset clusters have the same representation. As argued in chapter 5 and in 6.1 of this chapter, tautosyllabic unary NCs, such as those in Tamambo, and tautosyllabic NC clusters, such as those in Pamona, are not only phonologically distinct, but reflect these structural differences in their phonetic timing, with clusters being longer than single segments. These phonological differences should therefore be reflected in their representations.[9] Nevertheless, the aperture model makes some predictions about NC structures that are borne out by the data, particularly where NC affricates are concerned. A model that incorporates the restrictive nature of the aperture model whereby segments can have at most two positions, but also recognizes that the same phonetic sequence can be either a single segment or cluster of two, may be on the right track. For example, in addition to NC̥ clusters being represented with four underlying A positions (rather than two), voiced NC sequences would be single segments (two positions) in some languages but two segments (four positions) in others. Whether or not adding this additional layer of complexity into the aperture model can be justified, while still preserving all of the original motivations for this model, remains to be determined. Meanwhile, the representations proposed in figure 6.16 are able to capture the attested contrasts.

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[9] Less clear, in an aperture model, is how medial heterosyllabic NC clusters, such as those in Manado Malay, should be represented. If they differ from medial tautosyllabic clusters in having four A positions (two for the nasal coda and two for the onset stop—CR.CR, perhaps reducing to three given the coda position of the first nasal and frequent loss of release in this position—C.CR) rather than two, then they should have different phonetic patterns, which they do not.

6.5.2 Relative nasal-oral timing patterns

The fact that NC clusters have the timing of two segments and unary NC sequences have the timing of one is easily captured if the former are associated with two root nodes and the latter with one. What is not captured by the phonological representations, however, is the relative patterning of nasal and oral phases, which differs according to the voicing specification of the obstruent but not according to the phonological status of the sequence. These observations must be attributed to phonetic implementation.

In NC clusters, where two root nodes contribute to timing, one might predict that the combined duration will divide into two halves—half of the duration consisting of a nasal closure and half consisting of an oral closure and/or release. In the voiced NC clusters, however, almost the entire duration of the sequence is nasal, as discussed in chapters 4 and 5. The fact that this observation holds across all of the tokens in the data, and the fact that it applies to both the clusters and the unary segments—despite their different phonological structures—suggests a phonetic account. This pattern can be attributed to a combination of perceptual and articulatory factors discussed in chapter 1, section 1.4: an oral closure is not necessary for the perception of these sequences (simply an oral release), and it is easier for the velum to remain open or to raise gradually than to precisely time a closure before the release. For NC̥ clusters, on the other hand, the pattern is more as expected, with roughly the first half consisting of a nasal closure and the second of an oral closure and release. This pattern is also phonetically-motivated, however, and not only due to phonological structure. A substantial oral closure and/or fricated release (depending upon the obstruent-type) is necessary to lend the percept of a voiceless stop.

6.5.3 Implications: Other types of nasal contour segments

In addition to prenasalized stops, post-stopped nasals (such as n^d), pre-stopped nasals (such as ^dn) and medio-nasal segments (such as $^dn^d$) have been described. The primary question to ask about each of these sequence-types is whether or not they are contrastive. If they are contrastive, then they must be captured by the phonological representations, and the representations will make predications about their phonetic timing and voice qualities. If they are not contrastive, however, but allophones of plain nasals or other segments arising in particular phonetic contexts, then they may not need to be captured by the representations. In the following discussion, I address each of these sound-types in turn—how they would be represented (assuming representation is warranted) and what predictions about phonetic qualities the representations entail, as well as whether or not the sounds are even in need of phonological representation.

Post-stopped nasals were discussed in section 6.2.1.1. I suggested there that these segments are likely both phonologically and phonetically indistinct from prenasalized stops, under the assumption that the sounds indeed form unary segments. Therefore, like prenasalized stops, the sounds identified as post-stopped nasals would have a single root node, with the duration of a single segment and the same voicing specification throughout. (In cases where the sounds are found to form two segments rather than one, then the phonological representation and phonetic expectations would be identical to the NC clusters.) In terms of voicing, this prediction appears to be borne out, as these sounds are generally transcribed with a voiced oral portion; in any case, there are no reports of a voicing distinction in these segments (where voiced post-stopped nasals contrast with voiceless, for example). In terms of duration, there have not, to my knowledge, been any systematic studies comparing post-stopped nasals with single segments, but true unary cases should have the duration of single segments.[10]

Post-stopped nasals, like prenasalized stops, would be represented with [+nasal] linked on the left edge of a single root node and [-nasal] on the right (as seen in figure 6.16). With no variation possible in such a representation (no way to distinguish between two different unary NC stops with this nasal contour), the representation predicts no phonological distinction between these two reported sound-types. On the other hand, some cases of reported post-stopped nasals do not even appear to be phonological segments. This is the case with the post-stopped nasals in most dialects of Chinese surveyed by Chan (1987), where the sounds arise as allophones of syllable-initial plain nasals (with other conditioning factors varying by dialect). The post-stopped aspects of their character should therefore not necessarily be phonologically represented. Rather, these nasals attain their "stopped" portion as a phonetic consequence of producing a following oral vowel. In this case, there are no predictions about the voicing character of the oral portion (at least not based upon phonological specification), although a voicing contrast should not be possible, and the duration of the nasal segment would be expected to be similar to a plain nasal.

Pre-stopped nasals (also referred to as "pre-ploded nasals" or "post-nasalized stops") are found in a variety of languages, including Austronesian languages of Borneo (Blust 1997 and references therein), and are perhaps best known in languages of Australia (Dixon 2002 and references therein).

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[10] Durie (1985) reports that the post-stopped nasals in Acehnese are slightly longer in duration than plain nasals, but how much longer, and whether this is consistent, is unclear, as is the unary status of these sequences.

Typically described as unary segments, they would also have a single root node and be predicted to have the timing of a single segment and the same voicing specification throughout. (As above, it is possible that some reported cases of pre-stopped nasals are actually clusters, in which case they would have the representations and phonetic characteristics of clusters.) In terms of duration, there have been no systematic studies comparing the duration of these sounds with single segments, and this prediction is therefore in need of testing. Regarding voicing, there are no cases of a reported contrast between voiced and voiceless oral portions. Therefore, the prediction appears to be correct. Some of the pre-stopped nasals discussed in Blust's (1997) overview of nasals in Borneo are transcribed with a voiceless oral onset. Given the lack of acoustic studies, however, and the fact that those transcribing the languages were primarily interested in capturing the lack of nasality in the vowel, it is unclear whether or not the oral onset in these language is truly voiceless (although Blust cites Boutin and Howery 1991 as explicitly identifying that the velar cases have voiceless onsets in Bonggi). A small qualitative acoustic study of the Australian language Arrernte by Maddieson and Ladefoged (1993) finds that the oral portion of pre-stopped nasals is usually voiceless and that the nasal is also voiceless for approximately half of its duration. It may be that the entire sequence is phonologically specified as voiceless in Arrernte, or that speakers devoice a sequence that is specified as voiced, as seems to be the case with the prenasalized affricates in Tamambo. As mentioned, however, crucially no studies report that voicing is contrastive on these segments. (See Butcher 1999 for phonetic description of these sounds in several other Australian languages.)

Are pre-stopped nasals phonological entities in need of representation? In many cases, it appears that they are not. In the Borneo cases discussed by Blust, for example, these sounds arise as allophones of plain nasals when an oral vowel precedes. The oral portion of the consonant could therefore be viewed as a phonetic transition between the oral vowel and nasal consonant and would not need to be represented (nor subject to the predictions about voicing). There do appear to be cases where these sounds are phonological, however. In Arrernte, these segments are in contrast with plain nasals and stops and not predictable based upon the nasal or oral status of an adjacent vowel (Maddieson and Ladefoged 1993). Such sounds could be represented simply with a [-nasal] [+nasal] contour. Given the clear phonological evidence for the opposite contour, seen in prenasalized stops, there is no reason why pre-stopped nasals, differing simply in the ordering of the nasal specifications, should not be found. The representations presented here predict that they should occur.

Medio-nasalized segments have been reported in a few Brazilian languages of the Ge family—including Kaingang (Wiesemann 1972) and Karitiana (Storto 1999). Assumed to be unary, they would have a single root node and laryngeal node and predicted to have the duration of a single segment and the same voicing specification throughout. In terms of duration, the few phonetic studies of Karitiana (e.g. Storto and Demolin 2002) have not systematically examined this issue, and so it remains an open question. In terms of voicing, the sounds are typically transcribed with voiced oral portions, as expected, although again this issue has not been specifically studied.

These sounds are likely not in need of phonological representation, however. In all known cases thus far, they are allophones of plain nasals, arising when flanked by oral vowels in systems where the nasality/orality of the vowel is phonemic and must be maintained. Hypothetically, medio-nasal segments could be represented with a [+nasal] [-nasal] [+nasal] contour, and would therefore have three phases. However, such a representation is clearly undesirable as it would predict other three-phase contour segments that do not occur. If Steriade's (1993) assertion that segments can have at most two positions is on the right track, then medio-nasal segments would be predicted not to be possible phonological segments. I would agree that phonological cases will likely not be found, and that these sounds will only arise as nasal allophones in systems where nasal vowels are phonemic.

6.5.4 Summary of representations

In this section, I have proposed a set of representations for NC sequences. There are two crucial points that these representations are intended to capture. First, the representations must acknowledge the distinction between unary NC segments and NC clusters, a difference that is reflected in total duration. This point is achieved by assigning one root node to unary sequences and two root nodes to clusters. Second, the representations must limit the possible inventory of unary sequences; in particular, unary NCs with voiceless stops but voiced nasals should not be allowed. This point is also achieved by assigning a single root node to these sequences, which entails a single laryngeal node and therefore only one voicing specification. Unary NCs with a voiceless obstruent can be accommodated as long as the voicelessness can be attributed to the phonetics rather than the phonology; importantly, a phonological contrast in voicing of the obstruent portion is not possible. NC clusters, on the other hand, can have either a voiced or voiceless oral portion. In addition, the relative nasal-oral timing in the sequences was argued to be phonetic, and the implications of the representations for other nasal contour segments was discussed.

6.6 Chapter conclusion

This chapter began with an overview of the acoustic data based upon a comparison of the NC-types across the languages. Regarding total duration, I illustrated that unary NC segments and NC clusters do differ, in that unary NC segments are roughly the same duration as plain nasals while NC clusters are substantially longer than plain nasals. Regarding the relative nasal-oral timing within the sequences, I illustrated that there are no differences between unary and cluster NCs; rather, each NC-type (NC̬ stops, NC̥ stops, and NC affricates) has intrinsic characteristics that are consistent across the languages. Further, based upon the relative timing data from voiced NC sequences, I suggested that prenasalized stops do not differ from post-stopped nasals, another proposed unary NC-type. I also reviewed data on the release portions of voiceless stops and affricates, and found that the duration of aspiration is quite stable across the speakers and languages, while the duration of frication exhibits more variability.

On the basis of the phonetic results, I went on to offer explanations for the two primary typological facts identified in chapter 2, section 2.1. First, I argued that the lack of contrasting unary and cluster NCs within a language can be attributed to the fact that these sequence-types differ, significantly and solely, in the length of the nasal closure. This length difference can only be used contrastively in a language with phonemic length, where it is better analyzed as a singleton-geminate contrast. Second, I argued that the lack of prenasalized voiceless stops is due in part to the fact that they are necessarily long—closer to the length of two segments than one—and that this length contributes to their difficulty in being accepted as single segments, especially considering that the nasal and oral portions are always found independently.

Finally, I considered the representations of NC sequences. Based upon both the phonological patterns presented in chapter 2, section 2.1 and the phonetic results in chapters 4 and 5, I argued that unary NC sequences are represented with a single root node while NC clusters are represented with two. These representations are able to capture the total duration facts as well as the restricted inventory of unary NC-types. I also concluded that the relative nasal-oral patterns are phonetic, rather than phonological, in nature, and I discussed the implications of the representations for other proposed nasal contour segments.

6.7 Thesis summary, conclusions, and future directions

Summary

The question I set out to answer in this thesis is—*Are there different phonological NC patterns, and are these patterns reflected in the phonetics?* I addressed this question through a review of the cases in the literature, and by presenting new data collected during fieldwork on four Austronesian languages—Tamambo and Erromangan of Vanuatu, and Pamona and Manado Malay of Indonesia.

Ultimately, with the phonological and phonetic data presented in each chapter, I argued that the answer to both parts of the question is *yes*.

I began to address the phonological issues in chapter 1, by illustrating that there are clear cases of unary NC segments on the one hand, such as those in Fijian, and clear cases of NC clusters on the other, such as those in English. Although the NC sequences in many languages are harder to classify, there is ample evidence that these two distinctive cases do exist. I then proposed a methodology for analyzing the structure of an NC sequence. I argued that inseparable NCs, those where one phonetic element cannot occur alone, necessarily constitute unary segments, while heterosyllabic NCs, those where the nasal is in the coda and the obstruent in the following onset, are necessarily clusters. Tautosyllabic onset sequences may form unary segments or clusters, but I argued that the former analysis is only justified if there is strong corroborating evidence for such a treatment, and otherwise the sequences should be analyzed as clusters.

I continued the phonological discussion in chapter 2, beginning with a presentation of NC type combinations. By dividing the sequences in two ways—the unary-cluster distinction, and the voiced-voiceless obstruent distinction—sixteen type combinations are possible (including one with no NC sequences). Of these sixteen, I argued that only six are attested. The unattested ten cases can be attributed to two factors. First, prenasalized voiceless stops do not occur. Second, no language has a unary-cluster NC distinction (of the same voicing specification), at least not in the absence of a phonemic length distinction where the presumed contrast is better characterized phonologically as a singleton-geminate distinction. I then presented the phonological sketches of the four Austronesian languages undertaken for this study and categorized them on the basis of their NC patterns.

Having clearly demonstrated that NC sequences have different phonological patterns, I turned to the phonetic characteristics. I examined three phonetic factors often addressed in discussions of NC sequences—total duration of the sequence, degree of nasalization of the preceding vowel, and duration of the preceding vowel. After reviewing past studies, I determined that most studies of duration do illustrate that unary and cluster NCs have different realizations, despite contradictory interpretations in the literature. Data on the other two factors, however, are less consistent. Regardless, there have been too few studies of sufficient size and controlled design to view the results conclusively. I proposed four hypotheses to test with the data collected for this thesis. I argued that one of these, H3—that vowels preceding a nasal coda are shorter than those preceding a nasal onset—is not supported and did not warrant further investigation. The other three hypothesis were addressed in later chapters. Also in chapter 3, I presented the methodology used to undertake the phonological and phonetic studies reported in the thesis. I emphasized the importance of having data from multiple speakers, recording multiple repetitions, and striving to control for as many potentially interfering factors as possible (such as those that may impact segmental duration) when collecting the data.

In chapter 4, I addressed H4—that vowels preceding a nasal coda are more nasalized than those preceding a nasal onset. Through a presentation of the airflow data in Manado Malay, Tamambo, and Pamona, I illustrated that this hypothesis is not supported. Not only are vowels not consistently more nasalized before nasal codas in Manado Malay, but data from speakers of this language, as well as the two tautosyllabic languages, also exhibit great variability, suggesting a wide window during which the velum may lower at any point in preparation for a nasal consonant. Surprisingly, the one speaker in the study who has consistently more nasalization before NCs than plain nasals is a speaker of Tamambo, a language with no nasal codas; a tentative phonetic explanation was posited. In addition to the preceding vowel data, airflow data during the NC closures were presented. Across the languages, NC̬ sequences, of both phonological types, are almost entirely nasal, while NC̥ sequences are nasal for about the first two-thirds. Following vowel data were also briefly considered, and it was clear that there is strong progressive nasalization in all of the languages.

Hypotheses 1 and 2—that unary NC sequences are about the same duration as comparable single segments, and that NC clusters are substantially greater in duration than comparable single segments—were addressed in chapter 5 through a presentation of the acoustic data. The durational relationship between a plain nasal and NC sequence was found to be of most relevance in these comparisons, and data from all of the languages overwhelmingly support both hypotheses. The prenasalized stops in Tamambo and Erromangan are of comparable duration to plain nasals, in support of H1, while the NC clusters in both Pamona and Manado Malay are substantially longer than plain nasals (in both initial and medial position, and at the majority of places of articulation, while data on medial bilabials are less clear), supporting H2. NC̥ clusters in Pamona, Manado Malay, and Erromangan are also all substantially longer than plain nasals, although the difference is less pronounced in Erromangan, which I attributed to the fact that Erromangan has an NC̬-NC̥ distinction at only one place of articulation. I also presented acoustic data on the relative nasal-oral timing in the NC sequences, which corroborates the airflow data. These patterns do not relate to phonological structure, but rather each voicing and manner type has a characteristic realization across the languages independent of cluster or unary status. Voiced NCs are almost entirely nasal with only a brief oral period (which raised the question of whether or not prenasalized stops and post-stopped nasals are phonetically distinct, and I suggested that they are not), and NC̥s having three distinct phases—a nasal closure, an oral closure, and an oral release. NC affricates are unique in the variability they exhibit in the presence of an oral closure.

I offered an overview of the acoustic data through a comparison of the languages in chapter 6. I then returned to the phonological NC type patterns presented in chapter 2, section 2.1, and argued that the two gaps can be explained, at least in part, on the basis of the phonetic data. First, the fact that no language has a unary-cluster NC contrast can be attributed to the observation that the sequence-types differ—significantly and solely—in the length of the nasal closure, a distinction very similar to a singleton-geminate nasal distinction. Therefore, only in a language that already has this particular structural characteristic could a contrast between these two NC-types be maintained. Second, the fact that prenasalized voiceless stops do not exist can be attributed to a combination of factors—that languages always have plain voiceless stops and therefore such sequences are separable (and less ideal candidates for unary segmenthood), and the fact that NC̥ sequences are always phonetically long, contributing to their inability to pattern as single segments. Finally, I proposed representations of NCs that take into account the phonological and phonetic facts, arguing that both segmental structure (specifically how many root nodes the phonetic material is associated with), as well as prosodic structure (specifically how the root nodes attach to the syllable) are important. Unary segments have a single root node while both tautosyllabic and heterosyllabic clusters have two. These structures correctly predict that unary segments must have only a single voicing specification while clusters can have both. In addition, given that segmental duration is attributed to the number of root nodes, the representations predict that unary NC segments will be shorter than NC clusters. The implications of the data for the aperture model (Steriade 1993), and the predictions the proposed representations make for other partially nasal segment types, were also considered.

Conclusions

An issue central to our ongoing study of phonology is the degree to which phonology and phonetics are related. In this thesis, I have illustrated that the phonology can have distinct segmental patterns for the same apparent sequence of phonetic elements. In addition, I have argued that there is a direct mapping between the segmental structures in the phonology and their phonetic realizations, despite earlier speculation in the literature that there is no such mapping in the case of NC sequences.

It has become increasingly clear in the last few decades that sound sequences can vary across languages in how they relate to prosodic structure, and that these prosodic structures can have distinct phonetic realizations. This thesis calls for the need to recognize the importance of both prosodic and segmental structure to the phonology, as well as the phonetics (e.g. Ham 1998). Issues such as how a segment is syllabified, and whether or not it is associated with a mora, are important in explaining phonological patterns as well as phonetic affects, but so is how many segmental units a sound sequence forms. By recognizing the relevance of both structural levels, and the interaction they have with the phonetics, we can better understand the relationship between phonology and phonetics, as well as increase our understanding of the human capacity for language.

Future directions

The data presented in this thesis contribute greatly to the discussion of phonological and phonetic NC patterns. Nevertheless, the topics explored here could benefit from the contribution of data on a wider variety of NC-types and in a wider range of languages. In particular, duration data from languages with separable unary NCs would be valuable, as no such data are presented here. In addition, phonological and phonetic data on other partially nasal segments, such as post-stopped nasals, pre-stopped nasals, and medio-nasal segments, are needed. Some work in this latter category is currently being undertaken by Cohn and Riehl (2008, to be presented).

In general, additional phonological and phonetic NC data of all kinds from other languages, particularly from languages outside the Austronesian family, would also be of benefit to the discussion. It is my hope that I have provided both an approach and a specific methodology that others may use in undertaking such studies.

APPENDIX A:

NASAL ACCRETION IN PAMONA

In chapter 1, section 1.4, I discussed nasal substitution in Indonesian, the process whereby bimorphemic N+C̥ sequences are replaced by a nasal with the place of articulation of the stop (and the stop is deleted), arguably to avoid a dispreferred sequence of nasal + voiceless obstruent (for example, Indonesian /məN-tuŋgu/ 'to wait' surfaces as [mənuŋgu]). This process is discussed for Indonesian and various other languages by the sources listed in the aforementioned section.

Pamona offers some interesting and perhaps surprising data in this regard. Not only does Pamona retain a voiceless obstruent after a nasal in the same environment where Indonesian deletes it, but Pamona allows a nasal *only* before a voiceless obstruent, not before any other type of consonant or before a vowel. This pattern, sometimes referred to as *nasal accretion* (rather than *nasal substitution*), is seen not only with the addition of the active prefix, but in several other morphological environments as well, as described below.

In (A.1), I provide examples of this pattern in Pamona with the addition of the active prefix. (The examples make use of both the /mo(N)-/ and /ma(N)-/ prefixes; the difference between the two will not be addressed here, but they have the same behavior with regard to nasal accretion.)

(A.1)

a.	/p/	[mom-pau]	'talk'	[nda-pau]	(psv.)	*[ndam-pau]
	/t/	[man-tima]	'take'	[nda-tima]	(psv.)	*[ndan-tima]
	/k/	[maŋ-koni]	'eat'	[nda-koni]	(psv.)	*[ndaŋ-koni]
b.	/b/	[mo-basa]	'read'			
	/d/	[ma-doŋi]	'hear'			
	/g/	[mo-gele]	'laugh'			

c.	/l/	[mo-lontʃo]	‘run’			
	/w/	[ma-wai]	‘give’			
	/j/	[mo-junu]	‘befriend’			
d.[1]	/s/	[ma-soko]	‘catch’			
	/dʒ/	[ma-dʒila]	‘be tongue-like’			
e.	/n/	[ma-nawu]	‘fall’			
	/ŋ/	[mo-ŋari]	‘scream’			
f.	/ʔ/	[mo-ʔuki]	‘write’			
g.	/i/	[ma-isu]	‘touch’			
	/o/	[ma-oli]	‘buy’			
	/a/	[mo-apu]	‘make a fire’			
h.	/ŋg/	[mo-ŋgale]	‘move’	[nda-ŋgale]	(psv.)	*[nda-gale]
	/ndʒ/	[mo-ndʒumi]	‘whisper’	[nda-ndʒumi]	(psv.)	*[nda-dʒumi]

As can be seen, the nasal appears before the voiceless stops (a) (where a comparison with the passive prefix (psv.) reveals that the nasal is not part of the stem), but does not occur before the voiced stops (b). In addition, it does not appear before liquids or glides (c), before the fricative or affricate (d) (although this category is a bit more complicated, as described in the footnote), before nasals (e), or before glottal stop (f). Interestingly, the nasal also does not appear before vowel-initial roots; instead, the addition of the prefix results in hiatus (g). (This also means that it is not possible to determine the place (if any) of the prefixal nasal, whereas in Indonesian, the appearance of a velar nasal before vowel-initial roots suggests the nasal is velar.) Finally,

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[1] When the active prefix attaches to /s/-initial roots, the results vary depending upon the root; in some cases the sequence surfaces as above; in other cases it surfaces as [ntʃ]; and in other cases either realization is possible. See Riehl (2006b) for additional discussion. Regarding /dʒ/, although it generally behaves as above, it sometimes patterns with the voiceless plosives and exhibits nasal accretion. Speakers are inconsistent in their realization of these forms.

(h) illustrates that NC-initial roots remain unchanged with the addition of the prefix.

There are several other prefixes where a nasal also appears before stems beginning with voiceless consonants but not before any other consonants or before vowels, including /pa(N)-/ ‘moment of X’ ([pampau] ‘moment of conversation’ but [pabasa] ‘moment of reading’) and /po(N)-/ ‘place of X’ ([poŋkoni] ‘place of eating’ but [pobasa] ‘place of reading’). Whether these prefixes always contain a nasal which is then lost before certain sounds, or whether a stem selects an allomorph of the prefix either with or without a nasal, is unclear.

Attachment of a prefix is not the only environment where nasal accretion occurs in Pamona. A nasal linking morpheme appears solely before voiceless obstruents in compounding, in the formation of numbers in units of ten, and in certain adjectival phrases such as /sa(N)-/ ‘together in one place’ and /waʔa(N)-/ ‘many’ (c). In some very common words or phrases, the nasal might be fossilized (for example, [karama**m**pale] ‘fingers’ from /karama +pale/; [radua**m**puju] ‘twenty’ from /radua+puju/); in other cases, however, the addition of this morpheme is clearly productive. In the following examples, the compounds (a) and adjectival phrases (b) are not necessarily common, and in some cases fairly unusual.

(A.2)
a.

/banua/	‘house’	/tontʃi/	‘bird’	[banua ntontʃi]	‘birdhouse’
		/toda/	‘frog’	[banua ntoda]	‘frog house’
but….		/boti/	‘monkey’	[banua boti]	‘monkey house’
		/asu/	‘dog’	[banua asu]	‘dog house’

b.

/tabo/	‘bowl’	[san-tabo] ‘together in one bowl’	[waʔan-tabo] ‘many bowls’
/kadera/	‘chair’	[saŋ-kadera] ‘together in one chair’	[waʔaŋ-kadera] ‘many chairs’
but…			
/bontʃo/	‘cage’	[sa-bontʃo] ‘together in one cage’	[waʔa-bontʃo] ‘many cages’
/duaŋa/	‘boat’	[sa-duaŋa] ‘together in one boat’	[waʔa-duaŋa] ‘many boats’

Pamona is not unique in exhibiting nasal accretion only before voiceless stops. Although the contexts vary somewhat, a preference for bimorphemic N+C̥ over N+C̬ is found in many languages of the area, including Mori (Barsel 1984), Padoe (Karhunen 1991), Moronene (Anderson 1999), and Kulisusu (Mead 2001), among others. In all of these languages, both NC̬ and NC̥ sequences occur monomorphemically. These data pose challanges for the *NC̥ claims.

APPENDIX B:

PRECEDING VOWEL DURATION

This appendix contains data on the duration of vowels preceding NC sequences and corresponding plain segments, discussed in chapter 3, section 3.1.4.1. The duration scale on the Y-axis displays 0-300 msec and is the same as that used for the consonant duration data in chapter 5, so that the plots can be easily compared. General information on interpreting the box plots can be found in chapter 3, section 3.2.5.

Manado Malay

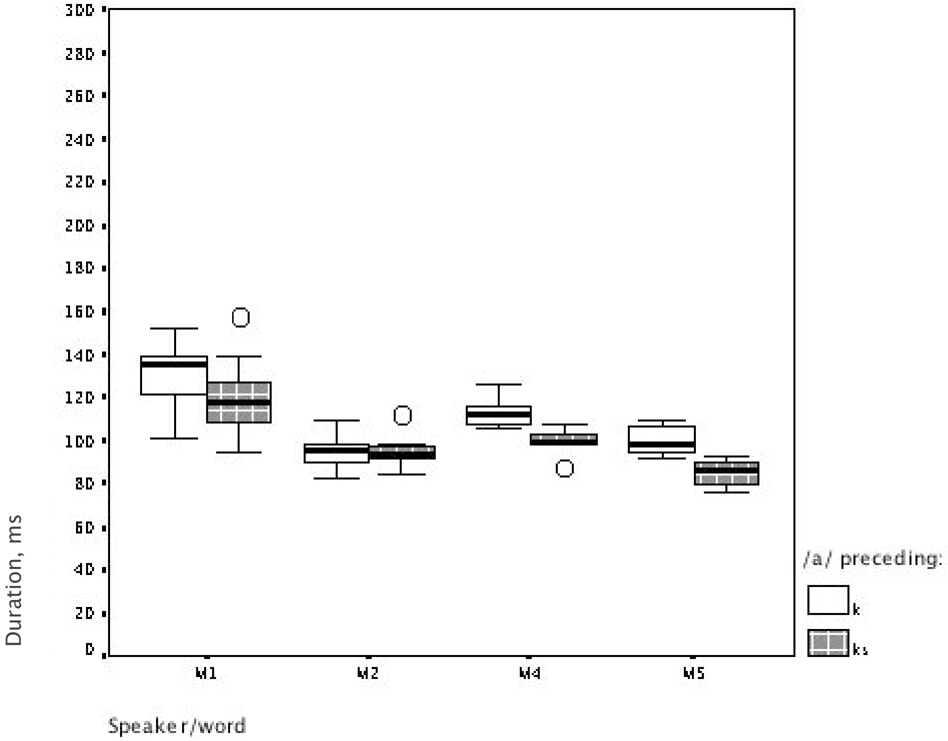

Figure B.1: Manado Malay. Duration of vowels before /k/ in /saki/ ‘sick’ and /ks/ in /saksi/ ‘witness’, for ten repetitions (except: M5 /k/–7, /ks/–6). (Consonant durations are in appendix C, figure C.1.)

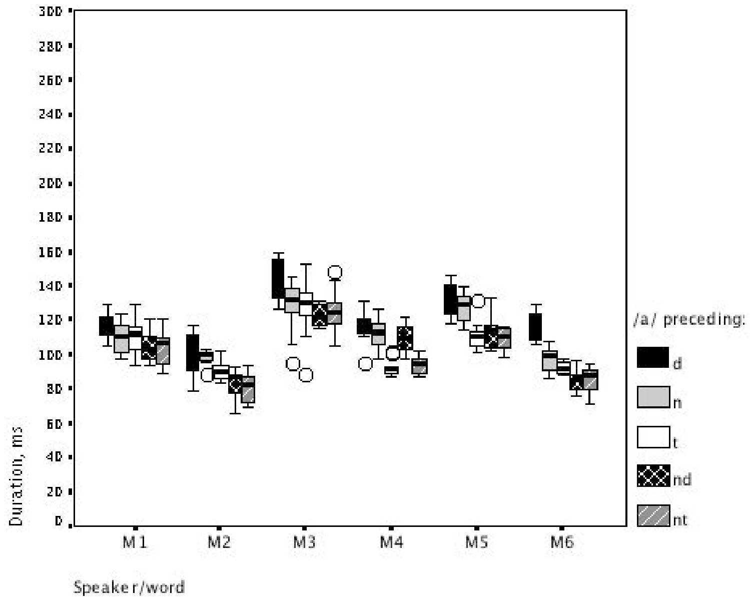

Figure B.2: Manado Malay. Duration of /a/ before /d/ in /tada/ 'to stomp', /n/ in /tana/ 'earth', /t/ in /tato/ 'tatoo', /nd/ in /tanda/ 'sign', and /nt/ in /tanta/ 'aunt', for ten repetitions (except: M3 /nt/–9). (Consonant durations are in chapter 5, figure 5.17.)

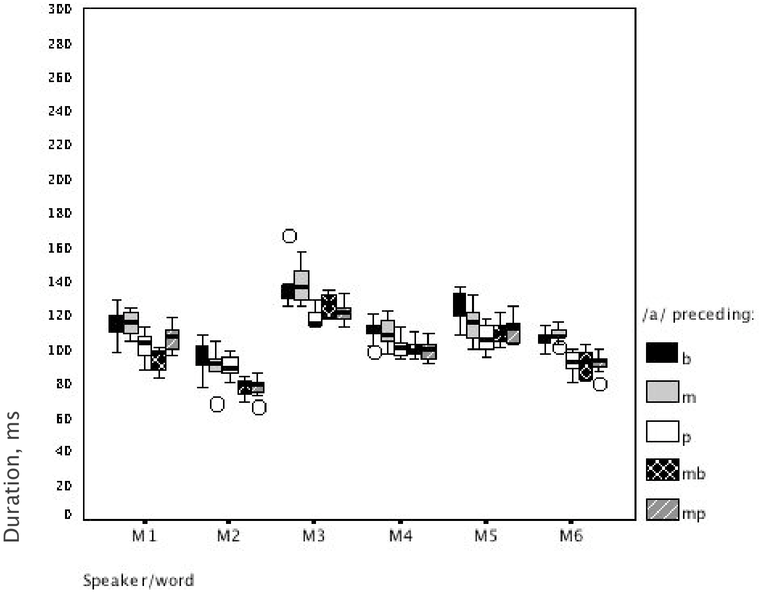

Figure B.3: Manado Malay. Duration of /a/ before /b/ in /taba/ 'patient', /m/ in /tamu/ 'guest', /p/ in /tape/ 'fried taro', /mb/ in /tamba/ 'to add', and /mp/ in /tampa/ 'place', for ten repetitions (except: M1 /mp/–6; M2 /m/–9; M3 /b/–9; M4 /b/–9, /m/–8; M5 /b/–8, /m/–8; M6 /t/–9). (Consonant durations are in chapter 5, figure 5.19.)

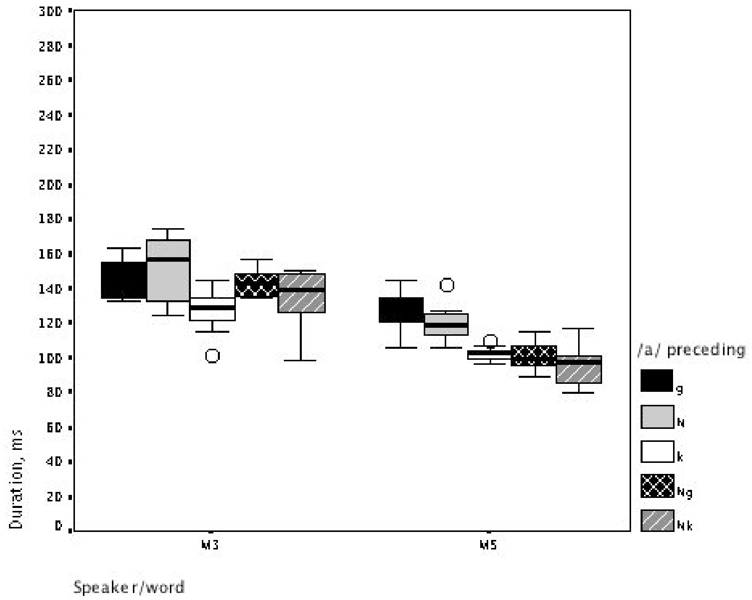

Figure B.4: Manado Malay. Duration of /a/ before /g/ in /pagi/ 'morning', /ŋ/ in /paŋi/ 't.o. vegetable dish', /k/ in /pake/ 'to use', /ŋg/ in /paŋge/ 'to call out', and /ŋk/ in /paŋko/ 'to hold in lap', for ten repetitions (except: M3 /ŋg/–6, /ŋk/–8; M5 /ŋ/–8, /ŋg/–7, /ŋk/–9). (Consonant durations are in chapter 5, figure 5.21.)

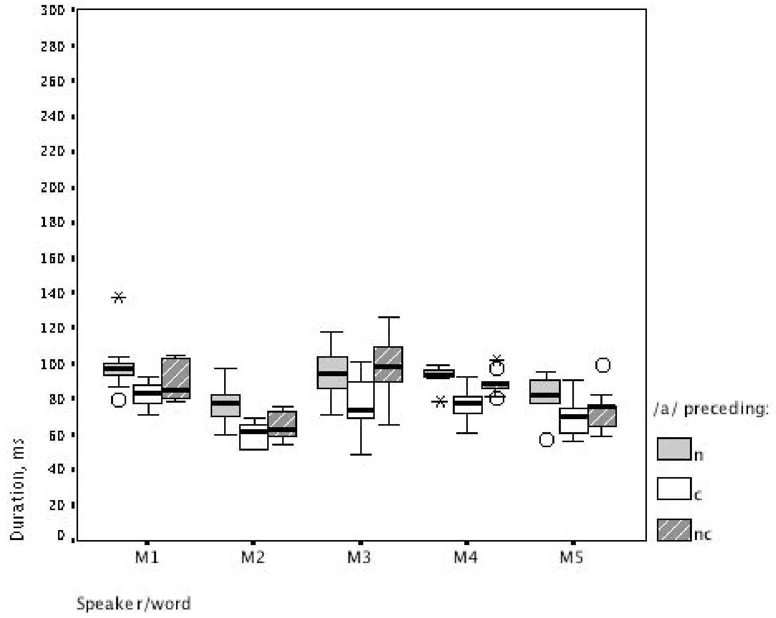

Figure B.5: Manado Malay. Duration of /a/ before /n/ in /kuno/ 'traditional', /tʃ/ in /kutʃa/ 'to scrub', and /ntʃ/ in /kuntʃi/ 'key', for ten repetitions (except: M2 /n/–8; M3 /ntʃ/–9; M5 /n/–9). (Consonant durations are in chapter 5, figure 5.23.)

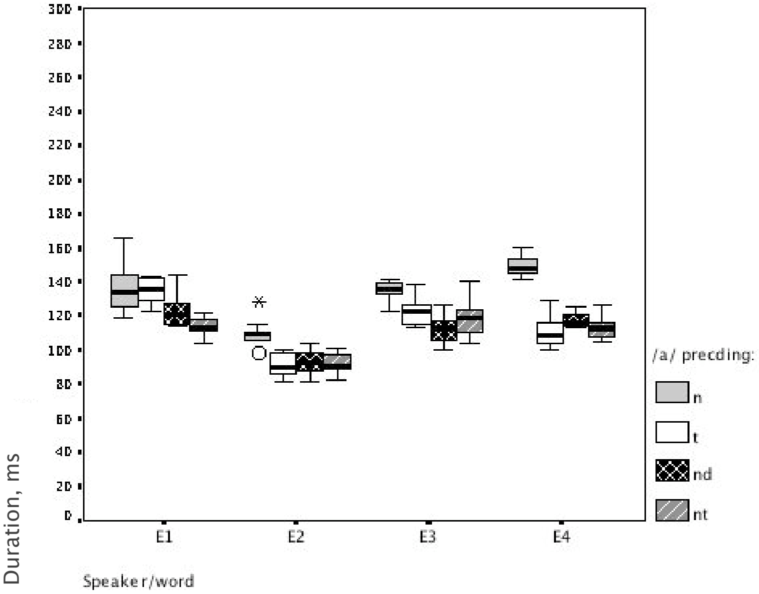

Figure B.6: Erromangan. Duration of /a/ preceding /n/ in /nani/ 'goat', /t/ in /natop/ 'hair', /^{n}d/ in /na^{n}dup/ 'bead', and /nt/ in /nantip/ 'banyan root' for ten repetitions (except: E4 /t/–7). (Consonant durations are in chapter 5, figure 5.42.)

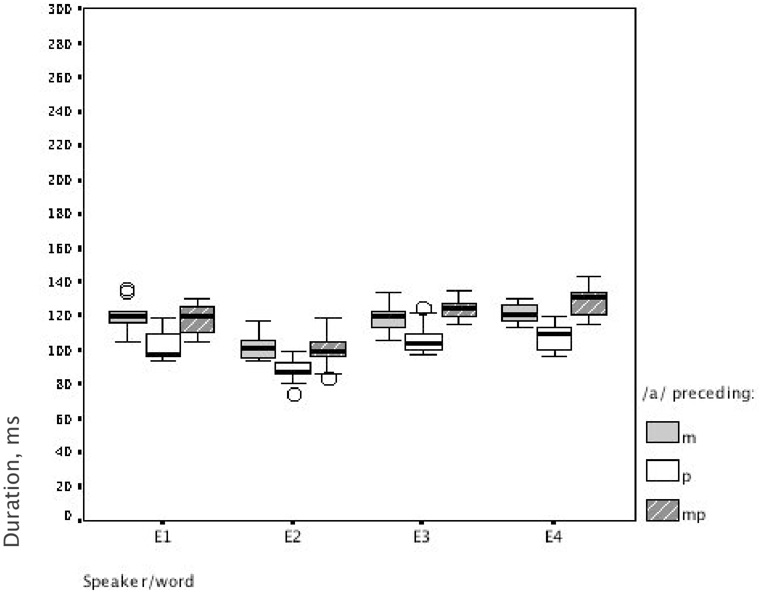

Figure B.7: Erromangan. Duration of /a/ preceding /m/ in /namou/ 'mother', /p/ in /napa/ 'to multiply', and /mp/ in /nampo/ 'whitewood tree' for ten repetitions (except E1 /mp/–9, E2 /m/–9, E4 /p/– 9). (Consonant durations are in chapter 5, figure 5.44.)

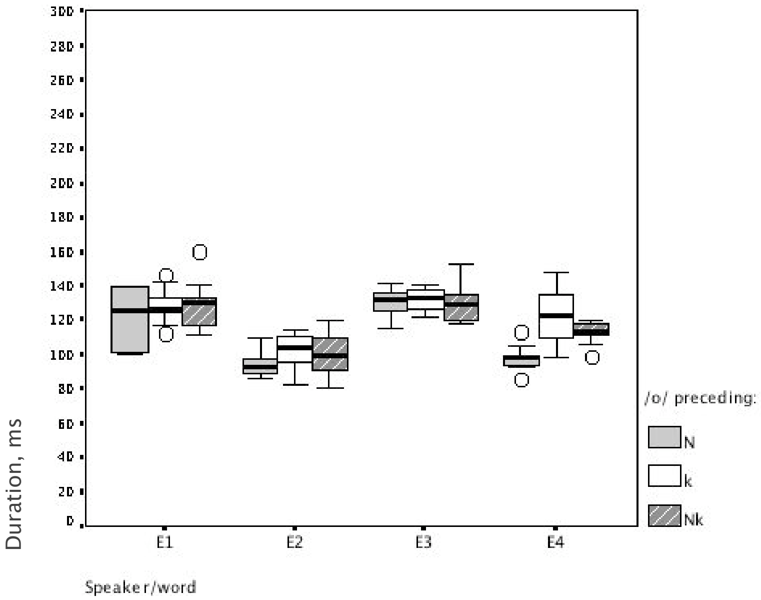

Figure B.8: Erromangan. Duration of /o/ preceding /ŋ/ in /noŋun/ 'mouth', /k/ in /noki/ 'coconut', and /ŋk/ in /noŋku/ 'beach' for ten repetitions (except: E1 /ŋ/–6; E2 /ŋk/–9, /ŋ/–7; E4 /ŋk/–9, /ŋ/–9). (Consonant durations are in chapter 5, figure 5.46.) [Note: "N" represents /ŋ/.]

Tamambo

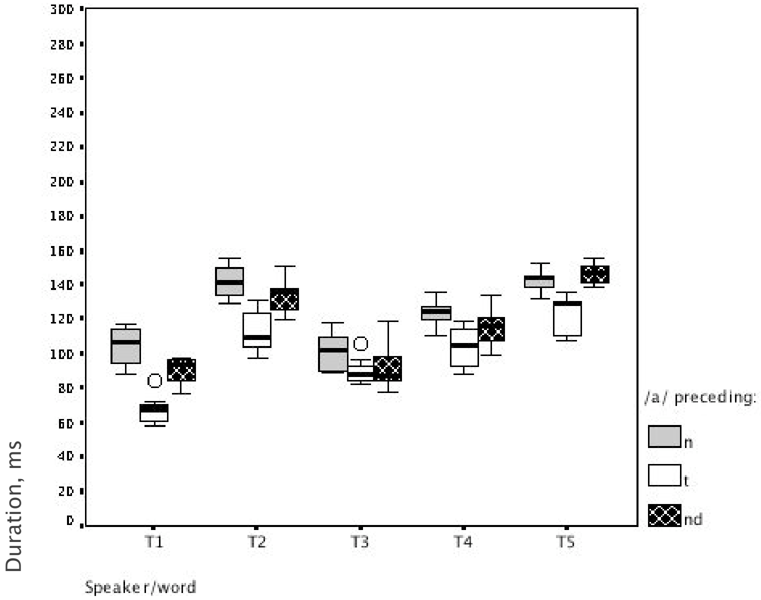

Figure B.9: Tamambo. Duration of /a/ preceding /n/ in /tano/ 'garden', /t/ in /tata/ 'grandmother' and /ⁿd/ in /taⁿda/ 'to look up', for ten repetitions. (Consonant durations are in chapter 5, figure 5.7.)

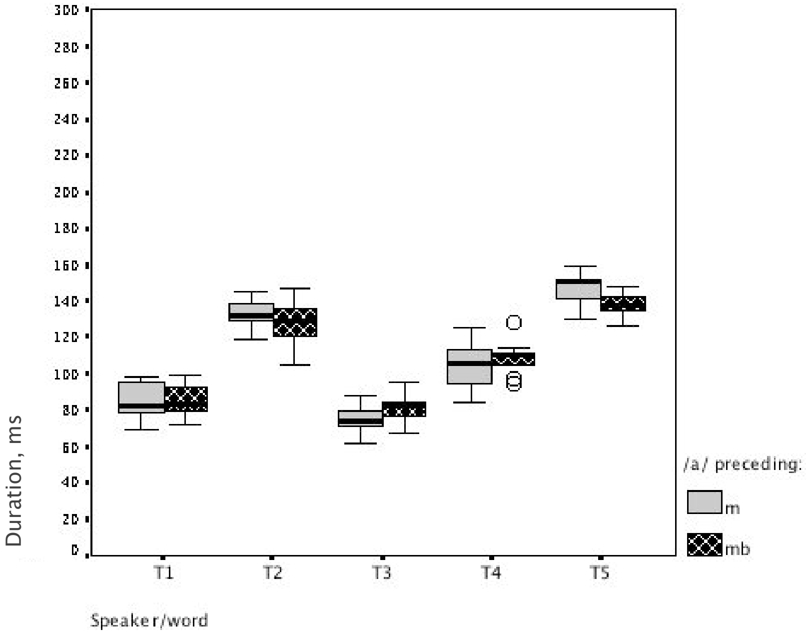

Figure B.10: Tamambo. Duration of /a/ preceding /m/ in /tama/ 'father' and /^{m}b/ in /ta^{m}ba/ 'to bump into', for ten repetitions (except T5 /m/–9). (Consonant durations are in chapter 5, figure 5.10.)

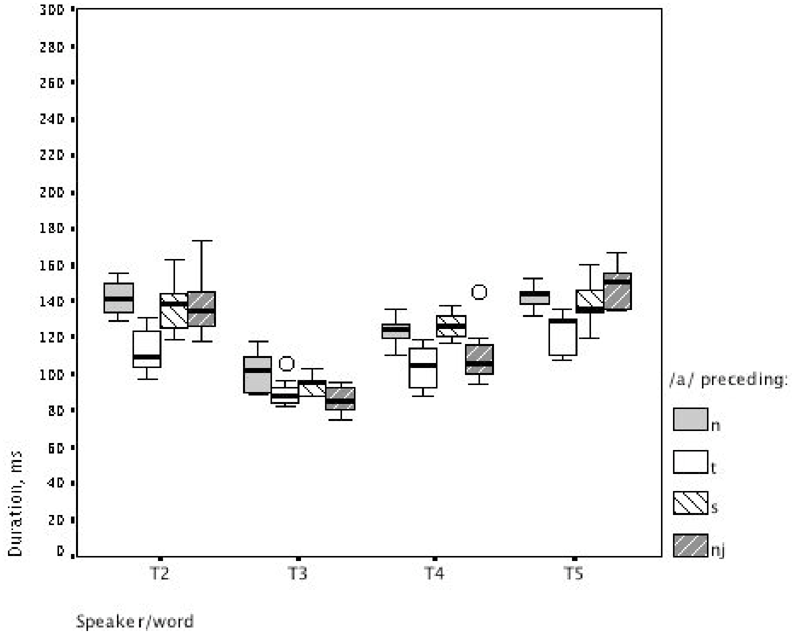

Figure B.11: Tamambo. Duration of /a/ preceding /n/ in /tano/ 'garden', /t/ in /tata/ 'father', /s/ in /tasi/ 'younger brother' and /^{n}dʒ/ in /ta^{n}dʒi/ 'to sharpen', for ten repetitions. (Consonant durations are in chapter 5, figure 5.19.) [Note: "j" represents /dʒ/.]

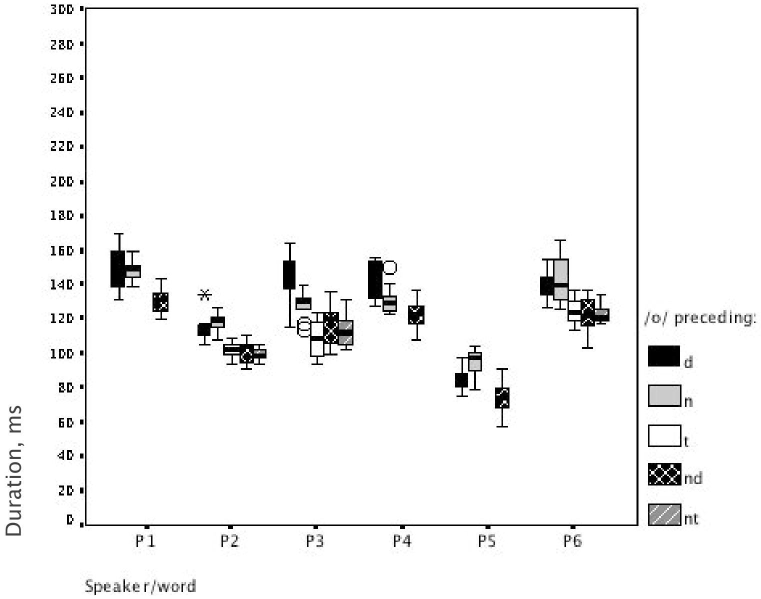

Figure B.12: Pamona. Duration of /o/ preceding /d/ in /todo/ 'at ease', /n/ in /tono/ 'to knock head', /t/ in /toto/ 'pair', /nd/ in /tondo/ 'next to', /nt/ in /tonto/ 'to empty out' for ten repetitions (except: P3 /nt/–9; P5 /n/–7; P6 /nt/–9). (Consonant durations are in chapter 5, figure 5.28.)

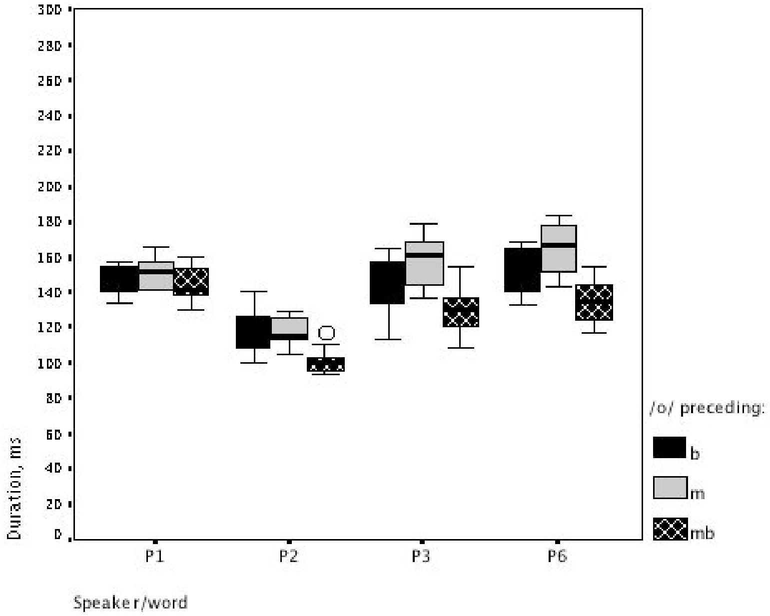

Figure B.13: Pamona. Duration of /o/ preceding /b/ in /tobu/ 'to gather', /m/ in /tomu/ 'to meet', and /mb/ in /tombu/ 'to draw water' for ten repetitions (except: P2 /m/–8, /b/–8; P6 /b/–8). (Consonant durations are in chapter 5, figure 5.31.)

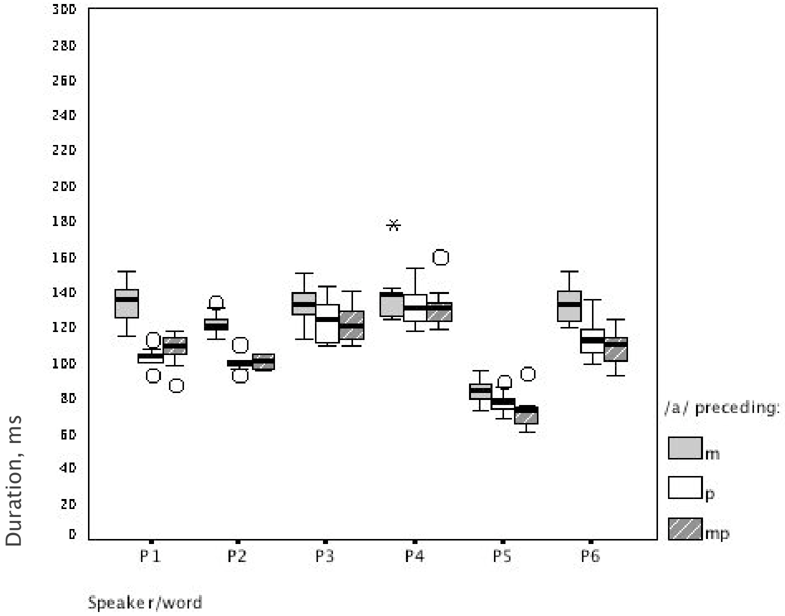

Figure B.14: Pamona. Duration of /a/ preceding /m/ in /tama/ ‘uncle’, /p/ in /tapa/ ‘to cook with smoke’, and /mp/ in /tampa/ ‘place’ for ten repetitions (except: P2 /mp/–9, P3 /m/–9). (Consonant durations are in chapter 5, figure 5.31.)

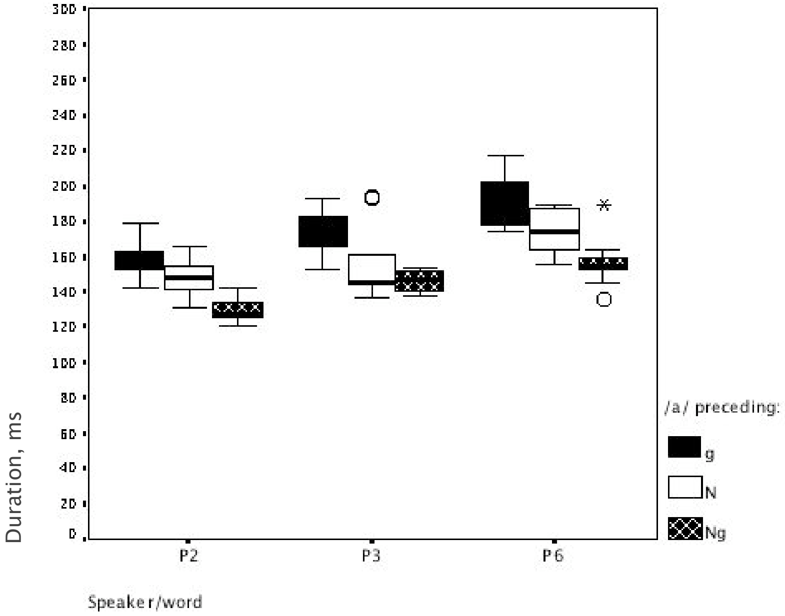

Figure B.15: Pamona. Duration of /a/ preceding /g/ in /dago/ ‘good’, /ŋ/ in /daŋa/ ‘spider’s web’ and /ŋg/ in /daŋga/ ‘incapable’ for ten repetitions (except: P2 /ŋ/–9, /ŋg/–9; P3 /ŋ/–9, /ŋg/–6; P6 /ŋ/–5, /ŋg/–9). (Consonant durations are in chapter 5, figure 5.34.)

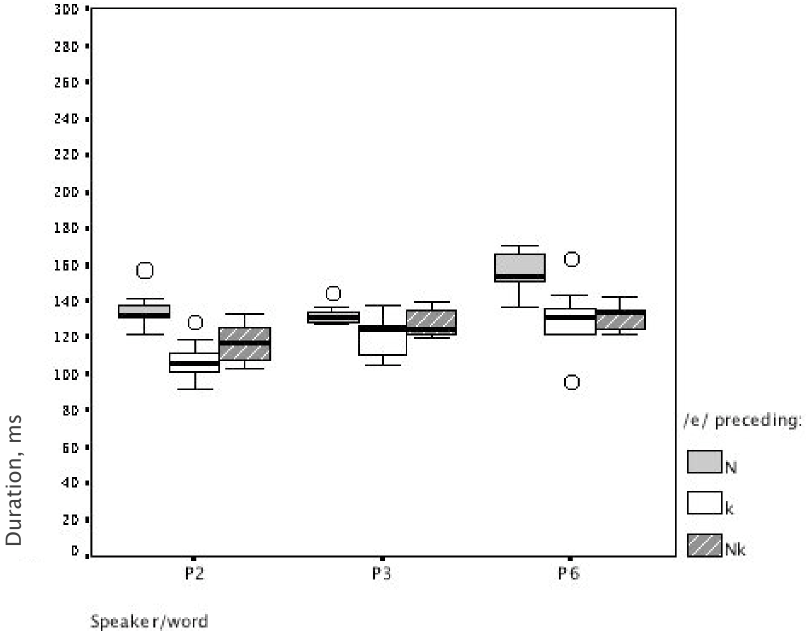

Figure B.16: Pamona. Duration of /e/ preceding /ŋ/ in /beŋa/ ‘to open’, /k/ in /beka/ ‘to cleave open’, and /ŋk/ in /beŋka/ ‘to split’ for ten repetitions (except: P2 /ŋ/–9, P3 /ŋ/–7, P6 /ŋ/– 9). (Consonant duration in chapter 5, figure 5.34.) [Note: “N” represents /ŋ/.]

APPENDIX C:

MANADO MALAY SUPPLEMENTAL DURATION DATA

/ks/ sequence

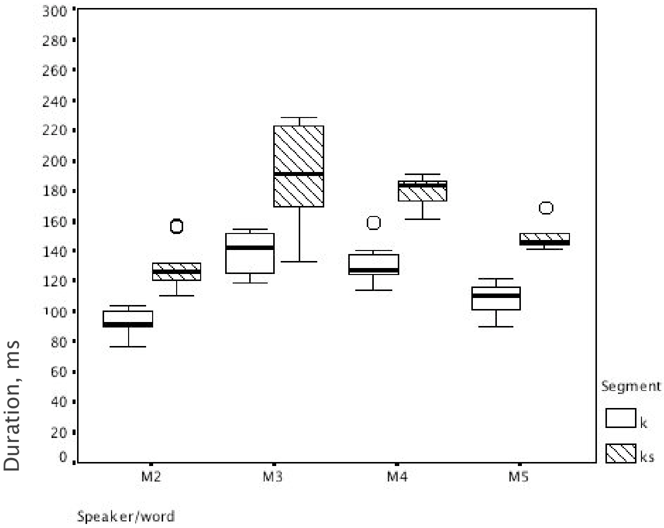

Figure C.1: Manado Malay. Duration of /k/ in /saki/ ‘sick’ and /ks/ in /saksi/ ‘witness’ for ten repetitions (except: M5 /k/–7, /ks/–6).

Initial (truncated) alveolars

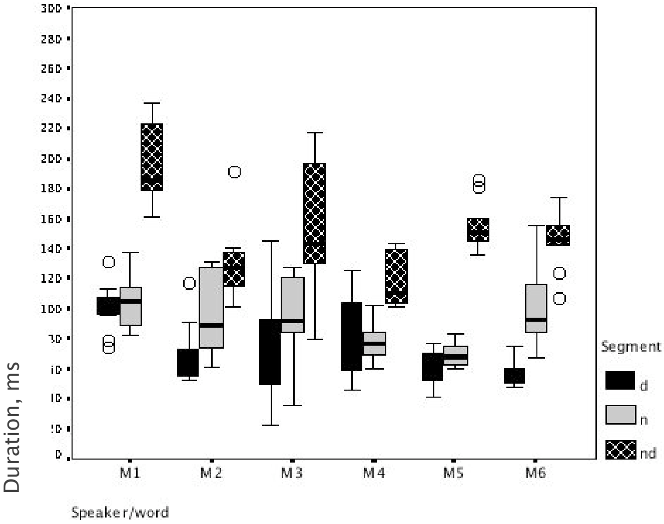

Figure C.2: Mando Malay. Duration of /d/ in /de/ ‘child (as term of endearment)’ (truncation of /ade/), /n/ in /naʔ/ ‘child’ (truncation of /anaʔ/), /nd/ in /ndaʔ/ ‘not’ (truncation of /ɲandaʔ/) for ten repetitions (except: M2 /d/–9; M5 /d/–8, /n/–9, /nd/–9).

APPENDIX D:

PAMONA SUPPLEMENTAL DURATION DATA

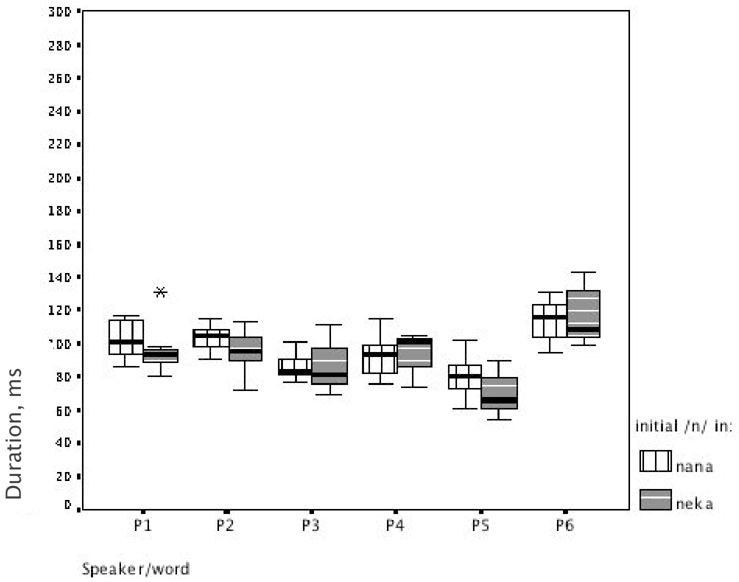

Figure D.1: Pamona. Duration of /n/ in initial position in /nana/ ‘wound’ and /neka/, a proper name, for ten repetitions (except: P1 /neka/–9; P3 /neka/–9; P4 /nana/–9, /neka/–9).

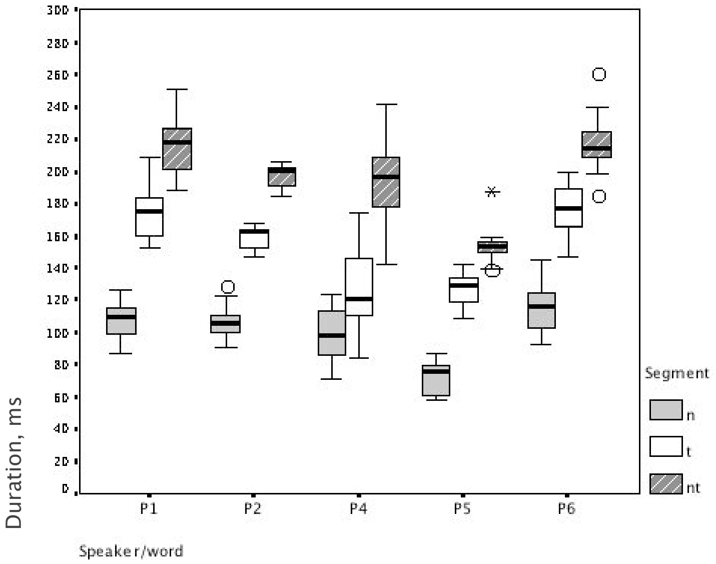

Figure D.2: Pamona. Duration of alveolars in medial position: /n/ in /oni/ ’sound’, /t/ in /oti/ ‘dry’, /nt/ in /onti/ ‘ant’ for ten repetitions (except: P4 /oni/–9, /onti/–8; P5 /oni/–9).

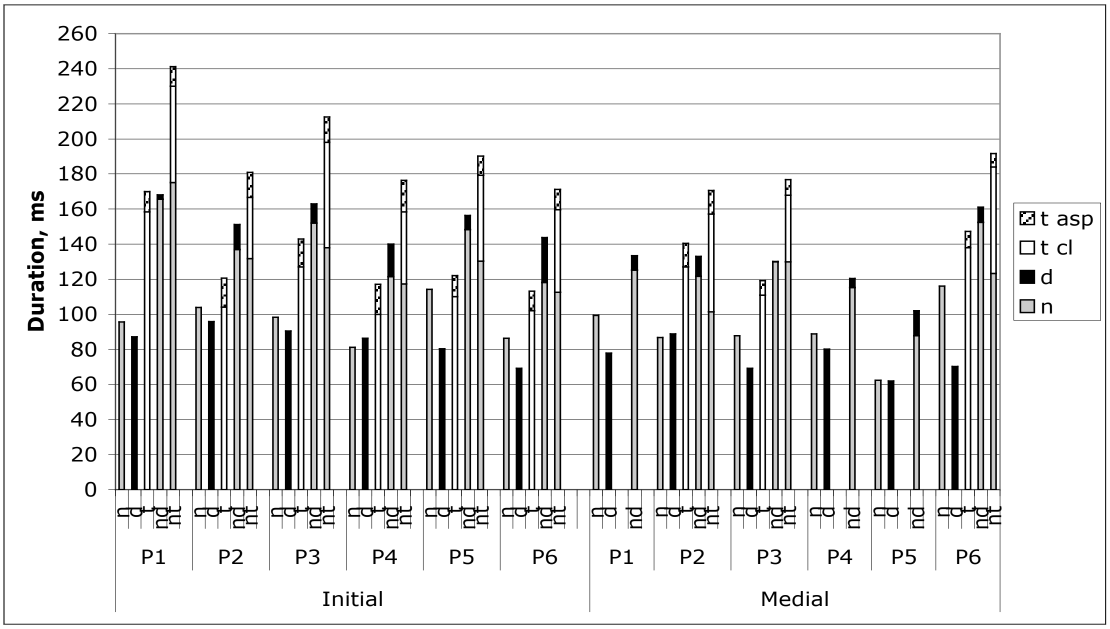

Figure D.3: Pamona. Average durations of component parts of alveolars in initial and medial position, based upon data in chapter 5, figures 5.27 and 5.28.

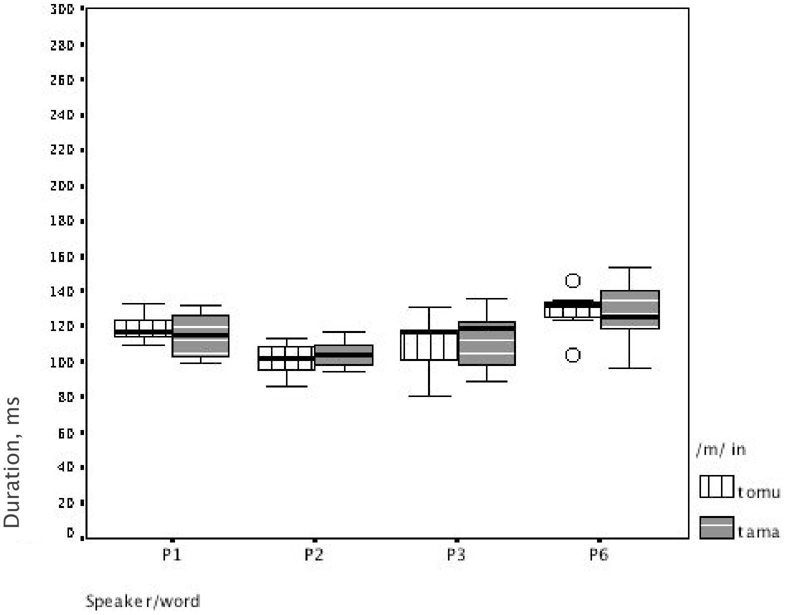

Figure D.4: Pamona. Duration of /m/ in medial position in /tomu/ 'to meet' and /tama/ 'uncle' for ten repetitions (except: P4 /tomu/–9, /tama/–8).

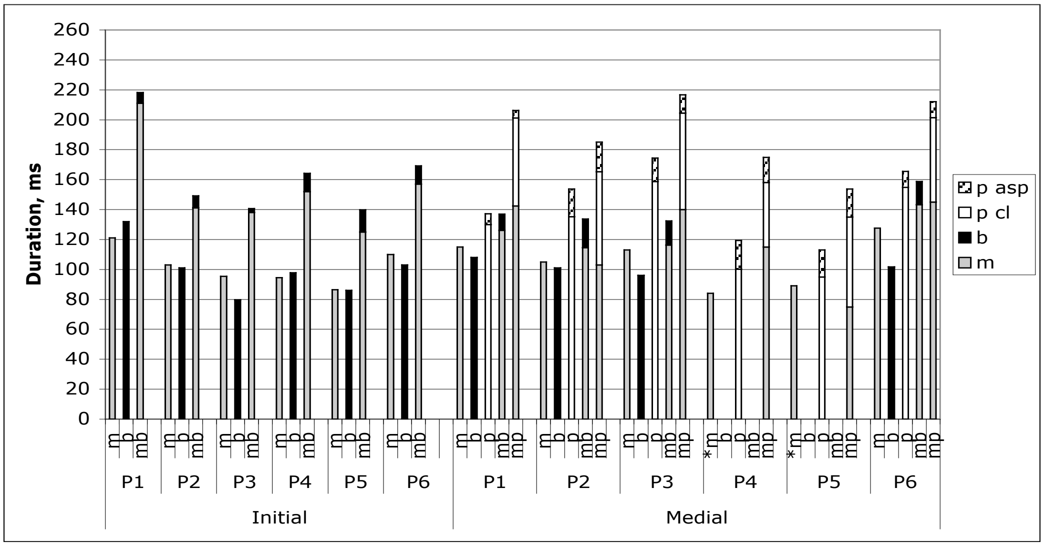

Figure D.5: Pamona. Average durations of component parts of bilabials in initial and medial position, based upon data in chapter 5, figures 5.30 and 5.31.

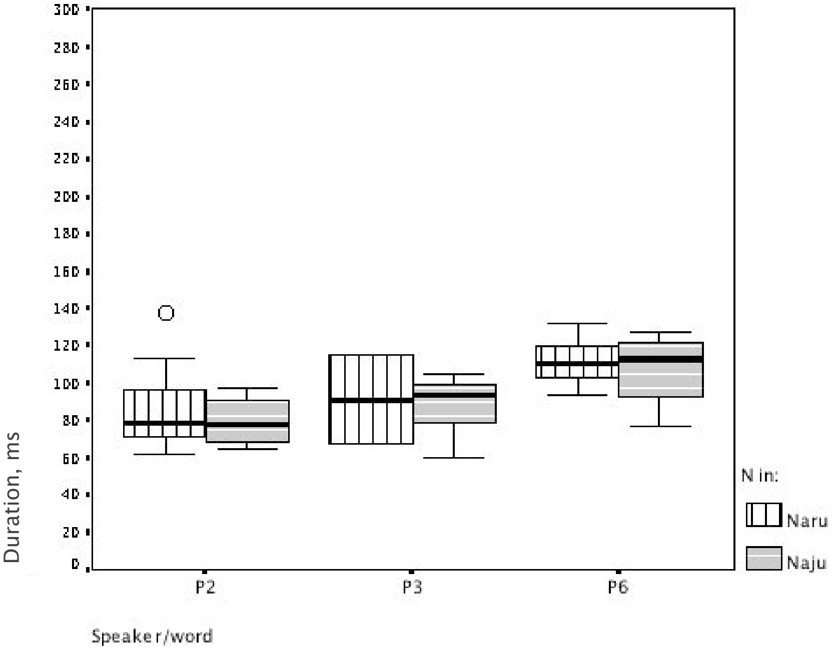

Figure D.6: Pamona. Duration of /ŋ/ in initial position in /ŋaru/ 't.o. traditional dance' and /ŋaju/ 'song' for ten repetitions (except: P2 /ŋgaru/–8, /ŋgkai/–8; P3 /ŋgaru/–2, /ŋgkai/–9; P6 /ŋgaru/–6, /ŋgkai/–4). [Note: "N" represents /ŋ/.]

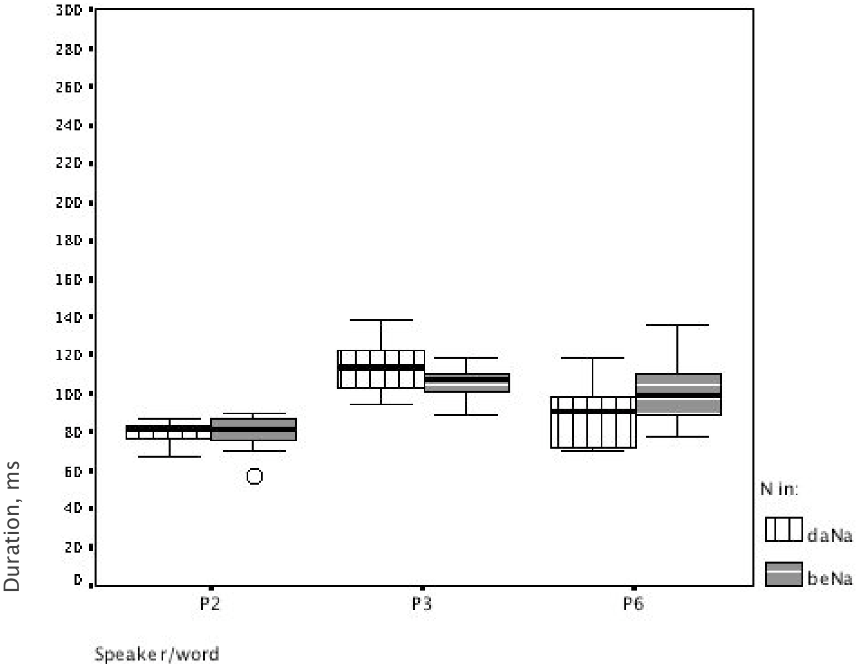

Figure D.7: Pamona. Duration of /ŋ/ in medial position in /daŋa/ ‘spider’s web’ and /beŋa/ ‘to open’ for ten repetitions (except: P2 /daŋa/–9, /beŋa/–9; P3 /daŋa/–9, /beŋa/–7; P6 /daŋa/–5, /beŋa/–9). [Note: “N” represents /ŋ/.]

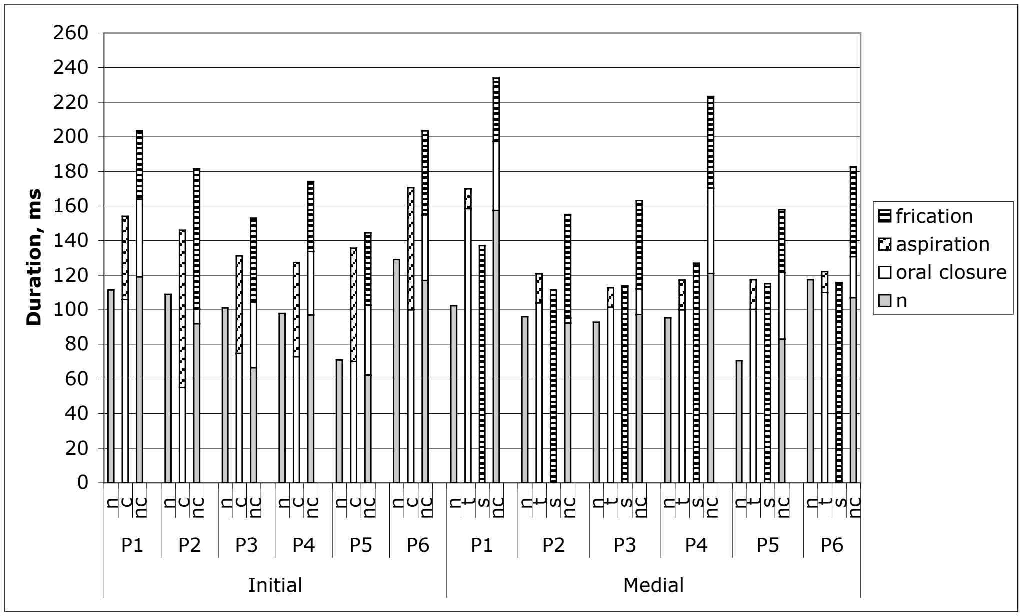

Figure D.8: Pamona. Average durations of affricates in initial and medial position, based upon data in chapter 5, figures 5.36 and 5.37. [Note: “c” represents /tʃ/.]

APPENDIX E:

ERROMANGAN SUPPLEMENTAL DURATION DATA

Additional alveolar initial set

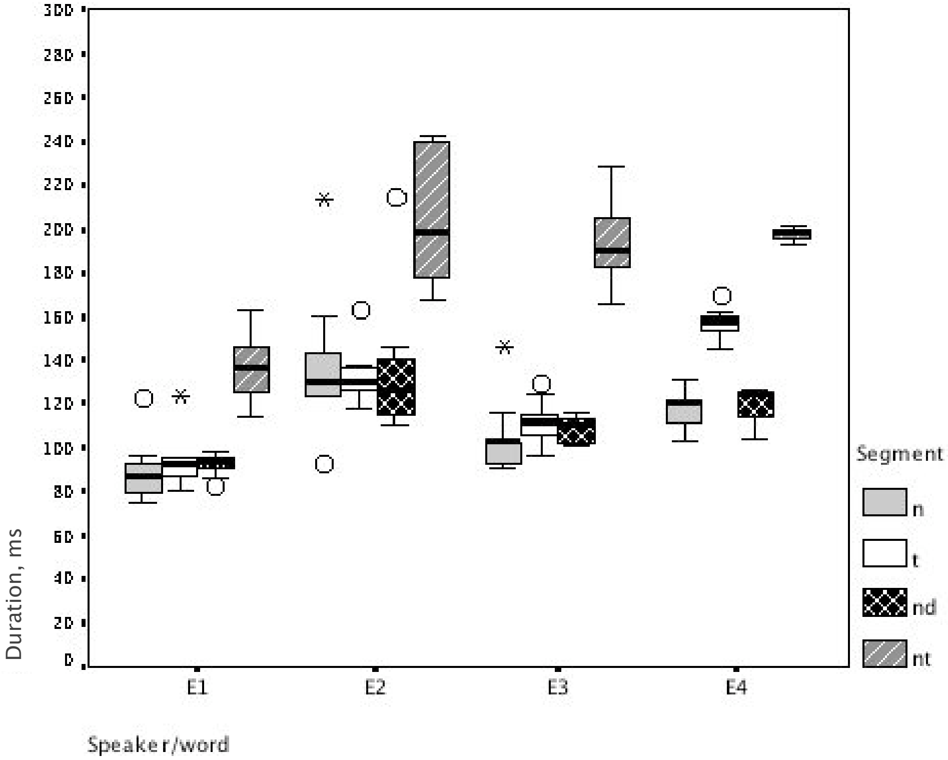

Figure E.1: Erromangan. Duration of alveolars in initial position: /n/ in /nau/ ‘bamboo’, /t/ in /tatu/ ‘tattoo’, /^{n}d/ in /^{n}dau/ ‘leaf’, /nt/ in /ntau/ ‘lychee’, for ten repetitions.

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