PHONETIC AND PHONOLOGICAL INFLUENCES OF JAVANESE ON INDONESIAN

A Dissertation
Presented to the Faculty of the Graduate School
of Cornell University
in Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy

by
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August 2004

BIOGRAPHICAL SKETCH

Niken Adisasmito-Smith was born in Malang, in the province of East Java, Indonesia. She is a bilingual speaker of Eastern Javanese and Indonesian. She received her bachelor's degree in French literature from *Universitas Indonesia* in Jakarta, and she received a master's degree in linguistics from the University of Colorado in Boulder, CO.

ACKNOWLEDGMENTS

Many people played an important role in the process of the completion of this work, directly and indirectly. To all of them I express my sincerest appreciation. I especially thank Abby Cohn for being an attentive advisor and a good friend at the same time. Her willingness to be flexible has made the process of long-distance advising less complicated. During the whole process of writing, she always encouraged me to see the forest without overlooking the individual trees — valuable advice for the time when raw data seem like a jumbled mess. I thank Draga Zec and John Wolff for their enthusiasm and support of my work. I also thank Amanda Miller-Ockhuizen for lending her expertise in voice quality as well as her insights on the overall work.

I appreciate the help of Eric Evans and Marek Przedzedzki who have provided tremendous help in extracting values for data analysis. Eric has also helped with the statistic analyses. I would like to thank Edith Aldridge, Tobey Doeleman, Eung-Yeong Kang, Lisa Lavoie, Rob Podesva, and countless others for their camaraderie.

I have been very fortunate to receive financial support without which it would not have been possible for me to carry out this study. Primary funding of this study was from NSF grant #SBR-9511185 to Abby Cohn. I have also received financial support from the Cornell University Graduate School, the Department of Linguistics and the South East Asian Program at Cornell University. I thank all of them.

While I was away from the Cornell campus, several individuals have provided assistance so that I could continue working on my acoustic data. I thank Jennifer Cole at the University of Illinois, Urbana-Champaign, Dr. Michael Mayfield, Kenneth Jacker, and Oscar Knight at the Appalachian State University, and Johanna Brugman, Emily Hanna, and Jonathan Square at Cornell University.

Many Indonesian speakers have participated in this study. I thank all speakers who have participated in this project and patiently let me take time from their busy schedules and who have shared their intuition about their language with me.

The following individuals have helped me with logistics during recordings: members of my family, Bambang Kaswanti, Tinuk Yampolsky, Bambang Sakri, Slamet Hariyanto, and Tituk. I thank all of them.

I thank my parents who have supported me throughout, spiritually and otherwise. I also thank Steve, for filling the gap in the daily family routines and providing support of all kinds, and Ryan and Kris who, in their own ways, have helped me see life in perspective.

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CHAPTER ONE:
INTRODUCTION

When different peoples come in contact, so do their languages. During the course of the contact, a linguistic exchange usually takes place. The extent of this reciprocal give-and-take depends on several factors, including time depth, the intensity, and the nature of the interaction.

In cases where languages come in contact with each other, the influence of one language on another is a common phenomenon, and in the use of either language, some linguistic features from the other are manifested. The influence may occur in the domains of phonetics, phonology, morphology, syntax, and semantics. The constituents being borrowed may come from a combination of domains. For example, certain lexical items and a set of phrases from Language A may be actively used in Language B; in other cases, certain aspects of a grammatical structure in Language A are adopted in Language B. At the level of phonetics, speakers may produce the phonetic details of a set of sounds that occur in one language, most likely their native language, when they communicate in another language. At the level of phonology, languages may differ in their phonotactic constraints and speakers may "transfer" the constraints in one language to the other. This borrowing process implies that one language serves as the source or donor language, from which a linguistic constituent is borrowed, and the other as the recipient one, in which a borrowed linguistic constituent is manifested. According to van Coetsem (1988), which constituents are transferred from which language depends on several factors, such as whether the constituents are part of the least stable or the more stable of the language domain. In addition, the issue of whether the source or the recipient language is either socially and/or linguistically dominant plays a major role in the process. These factors will be discussed further in § 1.1.

A goal in this study is to explore aspects of sound patterns in Indonesian and Javanese that are affected by the contact of the two languages, highlighting the interaction between phonology and phonetics. There are several issues in the investigation of the phonology/phonetics interaction that are relevant here. A central issue is how the discrete units of phonology are mapped onto the continuous units of phonetics. The linguistic influences, phonological patterns in particular, resulting from the contact between Indonesian and Javanese would be observable in the phonetics. Another relevant issue would be identifying whether what is observed in the acoustic data is phonologically relevant or not. This would require one to decide which phenomena are part of phonology and which are part of phonetics. These issues are further discussed in § 1.2.

There are three phonological phenomena that are investigated here: (1) *vowel alternation study*: the realization of the Javanese vowel alternation in the Indonesian of the bilingual speakers; (2) *voice quality study*: the realization of the Javanese breathy/clear contrast in Indonesian by these bilingual speakers; (3) *syllable structure study*: the syllabification of root-medial nasal + stop clusters in the Indonesian of the bilingual speakers. The three issues focused on here are acoustically and phonologically interconnected with each other, in that in order to investigate one, its interaction with the other is crucial. This is further discussed in § 1.8. For each phenomenon in question, I examine its acoustic realization in Javanese as produced by Javanese native speakers (who are bilingual) and in Indonesian as produced by monolingual Indonesian speakers. The results are then compared with those for the bilingual speakers producing sets of Indonesian forms.

The organization of this chapter is the following. In § 1.1, I discuss broad issues concerning language contact. In § 1.2, I discuss the interface between phonetics and phonology, and the ways in which it plays an important role in a systematic study of language contact. In § 1.3, I discuss the linguistic situation in Indonesia. In § 1.4, I discuss the location of the languages of interest. In § 1.5, the background of the interviewed speakers, their attitude towards language, and the recent tendency towards monolingualism are presented. In § 1.6, I discuss the sound inventories and sound patterns of Javanese, and in § 1.7, I discuss the Indonesian cases. In § 1.8, I discuss the interdependence of consonants and vowels. In § 1.9, the structure of this study is presented.

1.1 Issues of language contact

When two (or more) languages come in contact over a period of time, certain linguistic constituents from one language may manifest themselves in the other. Several issues that are important in language contact cases depend on (1) the dominance relation between the languages involved in the transfer, (2) the direction of the transfer, i.e. which language is the source of the transfer and which language is the receiver, and (3) the types of constituents subjected to the transfer.

With respect to the direction of borrowing, this phenomenon could occur unidirectionally, as in the case of a pidgin, wherein the donor language/s contributes linguistic features, either lexical items or grammatical constituents, to the pidgin language (e.g. Bakker, 1995; Romaine, 1988); but the reverse is not the case. Bidirectional borrowing seems to be the more common case. For example, while certain vocabulary items from languages spoken by the immigrants settling in the US are adopted into English, such as *spaghetti* from Italian, *delicatessen* from German, etc., the immigrant population (who would become bilingual) may also adopt English words into their language, as shown in the following example of a German utterance: *ich hoffe, Sie werden's enjoyen* 'I hope you'll enjoy it' (Bloomfield, 1933). One might assume that the direction of borrowing or influence would be from the more prestigious or more dominant language to the lesser one. The example above shows that this is not necessarily the case. English, being the dominant language relative to the languages spoken by the immigrants, nevertheless borrows constituents from these other languages. Van Coetsem (1988), for example, argues that there are two kinds of dominance, i.e. social and linguistic. I will discuss the issue of dominance momentarily.

Van Coetsem (1988) also argues that certain linguistic constituents are more likely to be borrowed than others, depending on whether these constituents are a part of the more stable or the less stable domain of language. Phonological, morphological and syntactical constituents have been found to be relatively stable and thus are less subject to borrowing, while lexical items are relatively less stable and are more subject to borrowing. There are at least two implications resulting from this tendency, especially where phonology is concerned. First, when a speaker of language A borrows a word (or a phrase) from language B, he or she would pronounce the word from language B according to the phonology of language A. For example, the last consonant in the German composer's name *Bach* is a velar fricative [x] in German, but it is usually pronounced as a velar stop [k] in English. Since the velar fricative is not part of the English consonant inventory, many speakers of English would substitute the velar fricative with the sound closest to it, being the velar stop.[1] Second, when a speaker of language A speaks language B, where language B is acquired later than language A or where speakers of language A feel closer affinity to language A than to language B, he or she would speak language B with an 'accent from language A'. This accent comes from the application (or *imposition* in van Coetsem's terminology) of the phonology of language A on language B. Note that fluency in either language is not necessarily at issue, since speakers may be equally fluent in both languages. For example, a native speaker of Javanese may (or is more likely to) speak Indonesian with a 'Javanese accent'. Javanese stops are either clear or breathy (e.g. Fagan, 1988; Hayward, 1993), while Indonesian stops are either voiced or voiceless. When speaking Indonesian, a native speaker of Javanese may impose the clear/breathy contrast of Javanese stops onto the two stop series in Indonesian; this imposition would be perceived as a manifestation of

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[1] Wolff points out that phonological influence is not just an issue of inventory, but also of expectation. For example, the German proper name *Handel* is pronounced as [handəl] by some speakers of English, but as [hɛndəl] by German speakers (Wolff, personal communication). While this example shows that writing system and expectation may lead to 'mispronunciation', it is not an issue of phonological borrowing per se, since both [a] and [ɛ] occur in the English vowel inventory.

'Javanese accent'. This is an issue focused on in the voice quality study (see Chapter 4).

Imposition may be due to prestige, or need, or a combination of both. This is determined by the dominance relation of the languages that come in contact. As mentioned earlier, van Coetsem argues that there are two kinds of dominance: social and linguistic dominance. Either the source or the recipient language may be socially and/or linguistically dominant. The interaction of these characteristics is schematized in (1).

(1) *Social and linguistic dominance*
(based on van Coetsem (1998), Figure 8, p. 14)

		RL[1] agentivity (borrowing)	SL[2] agentivity (imposition)
Inherent characteristics:		rl[1] linguistically dominant	sl[2] linguistically dominant
Motivation of occurrence of the two transfer types:	1. prestige and/or need	sl socially dominant	rl socially dominant
	2. need	rl socially dominant	sl socially dominant

Notes:
[1]RL or rl = recipient language
[2]SL or sl = source language

A term being used by van Coetsem is *agentivity* that marks one of the languages involved as linguistically dominant, being defined as the first language of the speakers. In the present study, the focus is on the influence of Javanese on Indonesian; thus its primary concern is the imposition of the Javanese system, particularly phonology, on Indonesian by the bilingual speakers. This is a case of *SL agentivity*.

To interpret the schema in (1), based on the interaction between Javanese and Indonesian where Indonesian is spoken with a 'Javanese accent', Javanese is first of all linguistically dominant, being the first language of most of the bilingual Javanese/Indonesian speakers.[2] Additionally, it is also the source language since the influence originates from Javanese. If Indonesian, being the recipient of influence, is socially dominant, the use of Indonesian may be due to prestige and/or need. If Javanese is socially dominant, in addition to being linguistically dominant, the use of Indonesian is due to need. Van Coetsem suggests that a shift in social dominance may result from a circumstance where language A is socially dominant in one area of social activity and language B is socially dominant in another such area. This implies that Indonesian that might be assumed to be more prestigious (or socially more dominant) than Javanese because it is spoken by the educated elite, by government officials, etc., is not necessarily always dominant socially. I will further discuss this phenomenon in § 1.5, in which the focus is the attitude of the interviewed speakers towards Javanese and Indonesian.

The present study focuses on the influence of Javanese phonology on the Indonesian of the bilingual Javanese/Indonesian speakers by providing systematic quantification of the acoustic manifestations of the influence. This requires us to review the ways in which phonological

[2] There are cases where the first language of a bilingual Javanese/Indonesian speaker is Indonesian, and Javanese is acquired later. Possibly, his/her 'Indonesian accent' would prevail in their Javanese. This is beyond the scope of the present study.

patterns and their acoustic manifestation inform each other. This is the focus in the following section.

1.2 Phonology and phonetics interface

Phonology and phonetics are usually argued to be separate areas of investigation. How sounds in a language pattern together is a focus of phonology. How these sounds are actually produced by speakers and perceived by listeners is the focus of phonetics. Phonological units are discrete, static, timeless, and thus *categorical*, while phonetic units are continuous, dynamic, and change over time, and thus *gradient*. A process like assimilation affects these units in a different way: a phonological assimilation causes change to a unit as a whole; a phonetic assimilation, usually referred to as coarticulation, shows the effect taking place over time. For example, [s] in English is palatalized lexically, in cases like *profession* (vs. *professor*), and post-lexically, in cases like *miss you* (vs. *miss him*). Based on an acoustic and electropalatographic study, Zsiga (1995) finds that the lexical palatalization in cases like *profession* is categorical, thus phonological. There is no acoustic or articulatory difference between palatalized [s] and underlying [ʃ], as in *mesh*. She finds, on the other hand, that post-lexical palatalization in cases like *miss you* is gradient and variable, thus phonetic. While acoustically [s] + [j] may be similar to [ʃ] at a certain point in time, articulatorily they are quite different. The difference between underlying [ʃ] and [s] + [j] is shown in Figure 1.1.

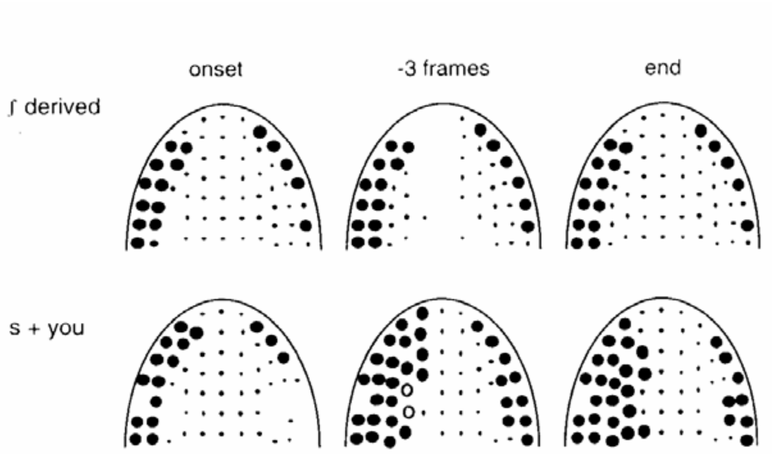


Figure 1.1: Palatalization in English (based on Zsiga (1995), Figure 20.5, p. 292)

There have been many discussions regarding the status of phonetics with respect to phonology. It had been assumed to be universal, the automatic realization of phonology, and to be outside of grammar (for example, Chomsky and Halle, 1968). However, recent findings have pointed to the conclusion that phonology is not the only part of speech that is subjected to language-specific restrictions, but that phonetics is subjected to them as well. This supports the view that at least some parts of phonetics are not mechanical and can be under the control of the speakers. This is a point that is well established and thus will not be repeated here. For detailed discussions on this topic, see for example Pierrehumbert (1980, 1990), Keating (1985, 1996), Kingston and Diehl (1994), Cohn (1995, 1998), Zsiga (1995), and other works in *Papers in Laboratory Phonology*.

In the present study, the main concern is the ways in which the discrete units of phonology are mapped to the continuous patterns of phonetics. This is a central issue in the study of phonology/phonetics interaction. The mapping of phonological units to phonetic ones assumes that the patterning of phonological units is manifested phonetically and that phonetic differences reflect phonological differences. For example, the phonological contrast in voicing of stops, in languages that make this distinction, would be realized systematically in terms of the vibration of the vocal cords during the stop closure for the voiced consonant cases and the lack thereof for the voiceless ones.

However, there are also cases where phonological patterns are not realized phonetically and where phonetic differences are not due to phonological differences. These cases are exemplified in the following. Word- or root-medial homorganic nasals may be syllabified in coda or in onset position, depending on the language. In English, homorganic nasals are in coda position (see, for example, Vatikiotis-Bateson, 1984), while in Fijian, they are in onset position (Maddieson, 1989). Maddieson (1985) argues that vowels tend to be shorter in duration when the following consonant is in coda position. This is not borne out in English, as the acoustic duration of vowels preceding medial homorganic nasals in coda position is comparable to that of vowels preceding medial consonants in onset position. An example of phonetic differences that are not phonologically relevant is the finding where female speakers of English are relatively breathier than the male speakers (see for example, Henton, 1987; Klatt and Klatt, 1990). While breathy voice quality is contrastive in some languages (e.g. Javanese, Khmer, !Xóõ, etc.), it is not in English.

In cases of language contact, certain linguistic features in one language are realized in the other. Claims about phonological borrowing have been based almost solely on impressionistic observations (for example, van Coetsem, 1988; Trudgill, 1983). While this method of investigation does not necessarily invalidate the claims being made, careful listening alone is not sufficient to provide us with the whole picture of linguistic (especially phonological) borrowing. Moreover, even an observant investigator would perceive sounds in categories (Repp, 1984), based on his/her own language. One the one hand, the manifestation of phonological borrowing may be subtle and best observable by way of acoustic investigation. On the other hand, it may not be so subtle, but the tendency to perceive in categories may mislead one to an inaccurate conclusion. In brief, by relying only on impressionistic observations, one may lose important information. Thus, the role of acoustic analyses in a systematic study of phonological borrowing is far from being trivial. In some cases, the analyses would provide quantitative data to corroborate the impressionistic observations, and in others lead to more subtle observations and conclusions.

The present study investigates three aspects of Javanese phonology that may be manifested in the Indonesian of the bilingual Javanese/ Indonesian speakers. The anticipated manifestations of two of the phonological phenomena focused on, i.e. the influences of Javanese vowel alternations and the relative breathiness of stops on Indonesian, are based on impressionistic observations. The third phenomenon, the syllabification of a homorganic nasal, is based on theoretical considerations. The discussions of each of these phenomena are presented in § 1.6 for Javanese and § 1.7 for Indonesian, and the hypotheses about the realization of the influence are discussed in detail in the relevant chapters.

I now turn to the linguistic situation in Indonesia, where several hundred languages are spoken. Some of these languages are in contact situation, providing a fertile ground for linguistic borrowing.

1.3 Linguistic situation in Indonesia

Indonesian and Javanese are two of several major languages spoken in the Indonesian archipelago. The Republic of Indonesia declared its independence from the Dutch and Japanese occupation in 1945. It consists of over 3000 islands of various sizes and has over 600 spoken languages (Grimes, 1996). The majority of these languages, such as Javanese, Madurese, Toba Batak, Sundanese, etc., belong to the Western Austronesian language family. However, some other languages, notably some of those spoken in the Moluccas islands and in Irian Jaya (Western Papua) do not belong to this language group (Grimes, 1996). Malay has been the lingua franca in the archipelago area for many centuries, and this is still the case now. Indonesian or *Bahasa Indonesia* (meaning ‘Indonesian language’) is a dialect of Malay.

In the early part of the 20^{th} century, during the Dutch occupation, many writers who were speakers of a Malay dialect, particularly the one spoken in Minangkabau, Central Sumatra, created a body of texts that are now considered the beginnings of Modern Indonesian literature (Herbert and Milner, 1989). Influenced by the increasing nationalism, among other factors, in 1928, the All Indonesian Youth Congress proclaimed the Malay dialect primarily used at the time by these writers as the national language, *Bahasa Indonesia*. With the declaration of independence in 1945, *Bahasa Indonesia* was declared the official language of the republic. Current standard Indonesian evolved from this Malay dialect, with changes due to the adoption of new vocabulary from various languages, especially Dutch and English. Note that there are existing borrowed lexical items in the language from Portuguese, Sanskrit, Chinese and Arabic (see Jones, 1984, for example). Writing conventions have also changed, from the conventions established by the Dutch to the new spelling conventions promoted by the Indonesian government in 1972. For example, the sounds [ǰ] and [č] represented as *dj* and *tj* respectively in the pre-1972 orthography were replaced by *j* and *c*, as in the following cases: *djurang* vs. *jurang* 'ravine' and *tjoba* vs. *coba* 'try'.

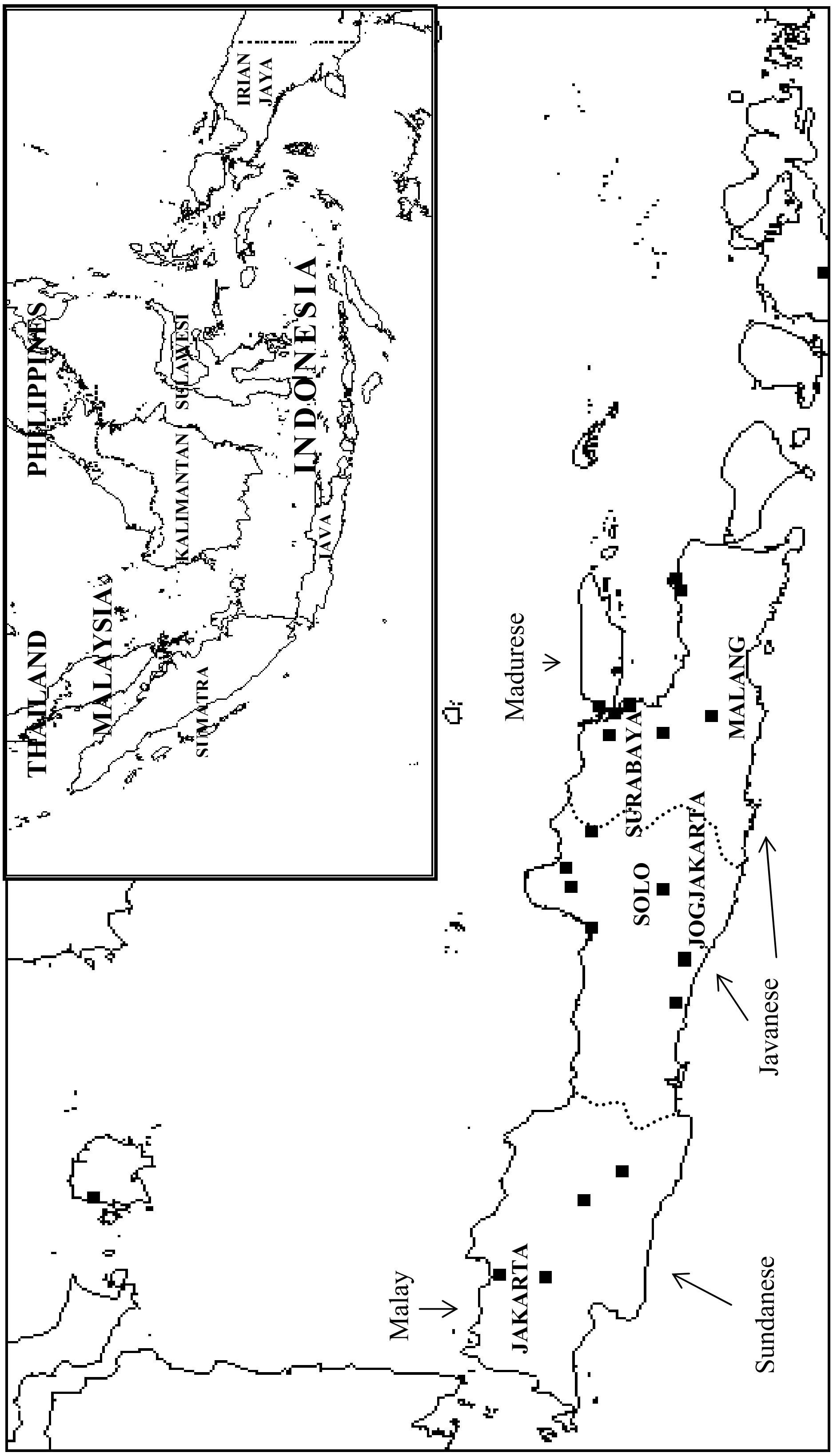
The contexts in which 'Standard' Indonesian is spoken are mostly formal. All government documents are written in Indonesian, and so are most national newspapers. TV and radio broadcasts are carried out in Indonesian, and so is instruction at school, where the majority of Indonesians acquire it as a second language (e.g. Poedjosoedarmo, 1982). The 'non-official' languages are usually spoken on other less formal occasions (including traditional ceremonies) and at home. Given such a setting, many Indonesians are at least bilingual, speaking Indonesian and a regional language.

Note that there is a difference between the written and the spoken forms of Indonesian. This phenomenon, referred to as diglossia (e.g. Ferguson, 1959; Romaine, 1988), is common in many languages, such as Classical vs. Colloquial Arabic, Standard vs. Swiss German, Literary vs. Spoken Greek, etc. In the case of Indonesian, the monolingual speakers write (and perhaps also speak) ‘Standard’ Indonesian. In addition, in unofficial occasions, they would speak the regional variety of Indonesian (or Malay). Thus, monolingual Indonesian speakers who live in the Jakarta areas would speak Jakarta Malay as well as ‘Standard’ Indonesian; those who live in Padang, Central Sumatra would speak Padang Malay (Minangkabau) and ‘Standard’ Indonesian; those from Riau would speak Riau Malay, in addition to ‘Standard’ Indonesian, etc.

1.4 Location

The data for this study are mainly obtained from speakers on the island of Java. On this island, there are several languages spoken by substantially big speech communities, e.g. Javanese, Sundanese, Jakarta Malay, and Madurese. The areas where these languages are spoken are indicated in the map in Figure 1.2.

Figure 1.2: Map of the island of Java, created in and downloaded from the Geoscience Interactive Databases (v1.0c) - Cornell University/INSTOC (http://atlas.geo.cornell.edu/webmap)


THAILAND
MALAYSIA
SUMATRA
KALIMANTAN
JAVA
SULAWESI
PHILIPPINES
INDONESIA
IRIAN JAYA
Malay
JAKARTA
Sundanese
SOLO
JOGJAKARTA
Javanese
SURABAYA
MALANG
Madurese

Indicated by dotted lines, the island of Java is divided into three provinces: West Java, Central Java, and East Java. In addition, Jakarta and the surrounding areas form their own administrative government, *Daerah Khusus Ibukota* (special federal district). Jogjakarta, about 60 km southwest of Solo, also forms its own administrative government, *Daerah Istimewa Jogjakarta* (Jogjakarta special district). In most areas of West Java, dialects of Sundanese (i.e. Sundanese and Badui (Grimes, 1996)) are spoken, in addition to Jakarta Malay. In Central Java, there are several dialects of Javanese. The dialect spoken in Solo and Jogjakarta has been the source of many studies on Javanese. In East Java, there are at least two dialects of Javanese, i.e. Surabaya and Malang-Pasuruan (Grimes, 1996). Based on the 1994-1995 census data provided by *Badan Pusat Statistik Indonesia* (Indonesian central bureau of statistics) (accessible online at http://www.bps.go.id/), the cities mentioned here are major urban areas with a population between 700,000 (for Malang) and over 9,100,000 (for Jakarta).

1.5 The speakers and their attitude towards their language/s

Based on the 13th edition of Ethnologue (Grimes, 1996), there are about 17-30 million native speakers of Indonesian, 75.2 million native speakers of Javanese, 27 million native speakers of Sundanese. The figure for Indonesian speakers seems to include only speakers, for whom Indonesian is the first language; these speakers are usually monolingual speakers of Indonesian. There are several dialects of Javanese, including the two dialects that are of particular interest in this study: the Central and the Eastern Javanese dialects. In this study, I recorded speakers from the city of Solo in Central Java and from the city of Malang in East Java. The reason for choosing these two particular areas is discussed in Chapter 2.

With respect to speakers' attitude towards their languages, especially Javanese and Indonesian in this case, there is a range of responses. Fluent in both Indonesian and Javanese, some speakers seem to have strong preference for one or the other language, while for others the preference is determined by context. During fieldwork in 1998, I interviewed eleven bilingual Javanese/Indonesian speakers from Solo and thirteen bilingual speakers from Malang. These speakers were also recorded for the phonetic case studies reported in this dissertation. In addition, I also informally interviewed other bilingual speakers whose speech was not recorded. See Appendix A for the list of interview questions and a brief summary of the response from the interviewed and recorded monolingual Indonesian and bilingual Javanese/Indonesian speakers.

Based on the response to the interview question of whether Javanese or Indonesian is preferred, four out of eleven Central Javanese speakers and six out of thirteen Eastern Javanese speakers claimed that they prefer to use Javanese. The reasons given are (1) that Javanese allows them to express events better than Indonesian, e.g. Javanese *k-undur-an* 'accidentally backed into (by a vehicle)' has no equivalent in Indonesian, (2) that they feel more at ease and less formal when conversing in Javanese, (3) that they feel uncomfortable speaking Indonesian with a 'Javanese' accent as compared to the TV broadcasters from the Jakarta stations, who in most cases originate from Jakarta.

For five of the Central Javanese and two of the Eastern Javanese bilingual speakers, many of whom are university students, Indonesian is preferred for discussions that require vocabulary that is absent in Javanese, such as matters pertaining to politics, economy, etc., while still preferring Javanese for informal communications. Two of the Central Javanese and three of the Eastern Javanese bilingual speakers claimed to have no preference between Javanese and Indonesian; for these speakers, the relevance of scene and setting of the speech event was more important than personal choice. These responses are examples of the fact that due to need, Indonesian, as the recipient language (i.e. recipient of 'Javanese accent'), is socially dominant when the discussion topic demands a wider scope of vocabulary not readily available in Javanese, or when the contextual need arises. Further, for the younger generation (under 30 years old), Indonesian is preferred because it is socially less complicated, lacking the high-mid-low register system that Javanese has. This tendency among the younger generation may suggest that one does not have to speak Javanese in all occasions to be perceived as an ethnic Javanese, while the older generation may still feel that speaking Javanese and being able to use the complex register system indicates one's ethnic background. In addition, this tendency among the younger generation may suggest that Indonesian gains social dominance, borrowing van Coetsem's term, in order to avoid the social complexity of Javanese. The fact that their Indonesian bears the influence from Javanese means that Javanese remains the linguistically dominant source language.

It is important to note that the social complexity of Javanese mentioned above is realized in the language in the form of speech levels/registers. There are three speech levels: *krama* (high register), *madya* (middle register), and *ngoko* (low register). These registers have been claimed to form a continuum, rather than distinct registers (Wolff and Poedjosoedarmo, 1982). For further detailed discussions on Javanese speech levels, see also Kartomihardjo (1971), Djajengwasito (1975), and Errington (1981, 1985). There are several factors governing their use, such as age of the speakers, social-economic status, degree of intimacy or distance of the speakers, etc. Most of the speakers from Central Java who were interviewed, claimed to be fluent in all three registers, even though some of them (especially the college-age speakers) claimed to be more comfortable speaking Indonesian to discuss certain issues. On the other hand, the speakers from East Java, who were mostly in their early twenties, claimed to feel most comfortable in using the low register, somewhat comfortable with the middle register, and much less comfortable with the high register. Several of the Eastern Javanese speakers admitted not to speak the high register at all.

Three FM radio broadcasters, who are bilingual Central Javanese/ Indonesian speakers, were also recorded and interviewed for this study. They claimed that an FM radio broadcaster has to learn to speak two varieties of Indonesian. One is the ‘regular’ Indonesian that they use in daily communications; the other one is the ‘formal’ Indonesian that they use in broadcasting. In the latter, they have to learn the ‘accent’ of the (monolingual) speakers from Jakarta. According to these radio broadcasters, an AM radio broadcaster does not need to learn how to speak the ‘formal’ Indonesian. The use of different varieties or styles of language among radio broadcasters has been found elsewhere. Bell

(1984, 1990) finds that newscasters who work simultaneously for two New Zealand radio stations would pronounce the word-medial alveolar stop in the word *writer* as a [t^h] or a flap [ɾ] depending on whether the audience of the news program is of high or lower socio-economic status. For the Javanese case, if the claim made by the FM broadcasters is true, then a Javanese newscaster who simultaneously works for a FM and an AM radio stations would read the news in 'formal' Indonesian in the FM station and in 'regular' Indonesian in the AM station.

When I asked to hear the difference between these two varieties of Indonesian, these Javanese radio broadcasters showed me what they considered to be the contrast between 'regular' and 'formal' Indonesian, by inviting me to listen to their speech while broadcasting. Impressionistically, the difference seems to be that 'regular' Indonesian is the kind of Indonesian that they use off the air, i.e. Indonesian with Javanese influence, e.g. breathy stops rather than voiced, or the word *tutup* 'to close' pronounced as [tutʊp]; meanwhile, in using 'formal' Indonesian, these speakers seems to attempt to produce the voiced/voiceless contrast of stops, and they pronounce [tutup] rather than [tutʊp]. Further systematic studies are needed to determine whether they in fact made these distinctions consistently, especially with respect to the voicing contrast.

These different attitudes among the bilingual speakers show that many, if not most, Javanese speakers are at least aware of the impressionistic distinction between vowels in open vs. closed syllables in Javanese and in Indonesian, and the distinction of stops in these two languages. A more systematic investigation, which is beyond the scope of the present study, would be needed to determine how widespread the attitude expressed by a very small sample of speakers here is.

Despite the high degree of bilingualism in Indonesia, there has been a growing tendency across ethnic groups for children to be raised with Indonesian as their first language (e.g. Nazar, 1991). I found this to be the case with one of the interviewed bilingual speakers from East Java. Formerly, the use of Indonesian was confined to formal situation and defined the interlocutors as non-intimate (Wolff and Poedjosoedarmo, 1982). An increasingly mobile population, where speakers of different ethnic background spend time outside the areas where traditionally their ethnic group lives, as well as an increasing number of inter-ethnic marriages, may have lead to the acceptance of Indonesian as an appropriate language to communicate in more informal/intimate situations. This tendency has resulted in an increasing number of monolingual speakers of Indonesian in different regions in Indonesia, even in areas where the use of a regional language is traditionally very strong. In Jakarta, for example, as the center of the political and economic activities, Indonesian is the primary language. Those born in Jakarta are mostly monolingual Indonesian speakers, keeping in mind that this means that they speak both Jakarta Malay and Standard Indonesian. Some of these speakers were recorded for this research, as the control group, to be compared with the bilingual group.

In order to analyze the influence of Javanese on Indonesian, we need to compare the sound inventories and sound patterns of Javanese and Indonesian. In § 1.6, I present the Javanese sound inventory and the distribution of consonants and vowels, both in the Central and Eastern dialects of Javanese, and in § 1.7, I present the Indonesian case.

1.6 Sounds and sound patterns in Javanese

Most phonetic and phonological descriptions and analyses of Javanese are based on the Central dialect, particularly the one spoken in the cities of Jogjakarta and Solo, in the province of Central Java (e.g. Dudas, 1976; Fagan, 1988; Hayward, 1993 and 1995; Wayland et al., 1994). These two cities, being seats of the Javanese royal palaces, are considered to be the center of Javanese culture and language, and hence the orientation for 'Standard Javanese'. In contrast, the linguistic structure of the Eastern dialect of Javanese is very much understudied. Unlike the Central dialect, there is no single place in East Java that is considered by the speakers of the Eastern dialect to be the center for standardization of their dialect.

The linguistic differences between the two dialects of Javanese appear to exist at the levels, but certainly at the levels of phonology and morphology. For example, in the Eastern Javanese dialect, all vowels in the penult syllable undergo vowel harmony when they are identical to the vowel in the final syllable, while for the Central dialect only the non-high vowels do (Adisasmito-Smith, 1999b). At the morphological level, there are variations in certain affixes with identical meaning. For example, the benefactive suffix in Central Javanese is *-ʔne* or *-ʔke*, while in the Eastern dialect it is *-ʔna*: *ŋgawaʔne* vs. *ŋgawaʔna* 'to carry s.t. for somebody'. With respect to differences in vocabulary, certain lexical items exist only in one dialect but not the other, such as the Central

Javanese *kowe* and *bočah*, and the Eastern Javanese *kɔn* and *arɛʔ*, meaning ‘you’ and ‘child’ respectively. With respect to their syntactic structure, there may be subtle differences that escape my observations; systematic comparative study is needed to verify this. Despite the differences mentioned above, the two dialects are still mutually intelligible.

I turn now to the discussion of sounds in both the Central and Eastern dialects of Javanese. There are six vowels in the inventory, as shown in Table 1.1.

Table 1.1: Vowels and their allophones in the Central and Eastern dialects of Javanese

	front	central	back
high	i		u
	[i, ɪ]		[u, ʊ]
mid	e	ə	o
	[e, ɛ]		[o, ɔ]
low		a	
		[a, ɔ]	

These vowels, with the exception of schwa, impressionistically undergo vowel centralization depending on syllable structure and vowel harmony. In open final syllables, non-low vowels are tense or in the periphery of the vowel space, such as in [watu̲] ‘stone’ and [čoro̲] ‘cockroach’. In closed syllables, they are lax or they centralize: [watʊ̲ʔ] ‘cough’ and [čɔrɔ̲ŋ] ‘funnel’. This vowel alternation takes place in both dialects. In the case of vowel harmony, which applies only to penultimate vowels, the two dialects do not behave exactly alike. In the Central dialect, only the non-high vowels are affected, while in the Eastern dialect, all vowels are. An example is the following: [pitɪʔ] (Central dialect) vs. [pɪtɪʔ] (Eastern dialect) ‘chicken’. See Chapter 3 for a more detailed discussion.

There are no diphthongs in Javanese, and two adjacent vowels are always heterosyllabic, as in [ka.ɪn] ‘cloth’ and [ra.ʊp] ‘wash face’. When two vowels become adjacent due to affixation, they coalesce. The examples in (2) illustrate this.

(2)	/kə + turu̱ + a̱n/	→	[kəturɔ̱n]	‘fall asleep’
	/kə + taŋi̱ + a̱n/	→	[kətaŋɛ̱n]	‘get woken up’
	/kə + sore̱ + a̱n/	→	[kəsorɛ̱n]	‘too late in the afternoon’

The consonants in Javanese occur in six places of articulation: bilabial, coronal, retroflex, palatal, velar, and glottal, and there are five manners of articulation: stop, nasal, fricative, liquid and glide. These are shown in Table 1.2.

There are two series of stops: clear and breathy. These series are both voiceless since the vocal cords in neither case do vibrate during the stop closure. This is manifested acoustically as the absence of voice bar (e.g. Fagan, 1988; Hayward, 1993; Adisasmito-Smith, 1999a). Given this fact, the breathy stops in Table 1.2 are represented here as voiceless (although orthographically they are represented with the symbols for voiced stops). The breathy vs. clear distinction is represented here with the IPA symbol [ʱ] following the phone, for the breathy stops. This representation, following that used by Maddieson (1984), reflects the acoustic realization of the Javanese breathy stops, in that they are acoustically voiceless and breathiness is realized on the sound following the stops (usually a vowel, but it may also be a liquid). One of the acoustic effects of relative breathiness is the lowering of fundamental frequency. For a detailed discussion, see Chapter 4.

Table 1.2: Phonemic consonant inventory of the Central and Eastern dialects of Javanese

		bilabial	coronal	retroflex	palatal	velar	glottal
stops:	clear	p	t	ʈ	č	k	ʔ
	breathy	pʱ	tʱ	ʈʱ	čʱ	kʱ	
nasals:		m	n		ɲ	ŋ	
fricatives:			s				h
liquids:			l, r				
glides:		w		j			

There are two sets of front coronal stops in Javanese, dental and retroflex stops. In most works, there is no issue regarding the dental stops. However, there are disagreements as to whether Javanese has retroflex (Fagan, 1988) or alveolar stops (Horne, 1974). Uhlenbeck (1978) distinguishes them as being without raised tongue tip, [t, tʱ] and with raised tongue tip, [ʈ , ʈʱ]. Based on electro-palatographic images, Hayward and Muljono (1991) find that the locations of constriction of [ʈ , ʈʱ] begin at the back of the alveolar ridge and end at just behind the upper incisors. The position where these consonants end overlaps with that of the dental consonants. The clear [ʈ], in particular, may be produced with the tongue tip as far back as the dome of the hard palate. Hayward and Muljono suggest that [t, $t^{ɦ}$] are dental, [n] is alveolar, and [ʈ , $ʈ^{ɦ}$] are alveolar/retroflex.

In the following section, I turn to the sound inventory and the patterns of these sounds in Indonesian.

1.7 Sounds and sound patterns in Indonesian

Similar to Javanese, Indonesian has a six-vowel system. The front and back mid vowels have centralized allophones, which are conditioned by syllable structure. These are shown in Table 1.3.

Table 1.3: Vowels and their allophones in Indonesian

	front	central	back
high	i		u
	[i]		[u]
mid	e	ə	o
	[e, ɛ]		[o, ɔ]
low		a	
		[a]	

In addition to these monophthongs, Indonesian also has diphthongs that can occur only in root-final position: [ɛj], [ɔw], [ɔj], as in [pakɛj] ‘use’, [limɔw] ‘citrus’, and [ambɔj] ‘wow’, respectively. The diphthong [ɔj] occurs in a much smaller number of words, which include exclamatory statements and borrowed words, e.g. [kɔbɔj] ‘cowboy’, etc.

In addition to being different in terms of the occurrence of diphthongs, Indonesian and Javanese are also different with respect to the patterning of the vowels. Impressionistically, in Indonesian, only mid vowels undergo centralization depending on syllable structure and vowel harmony, while in Javanese high and mid vowels do. Based on impressionistic observations, high and low vowels in Indonesian do not undergo vowel centralization (cf. Lapoliwa, 1981, for example).

With respect to consonant inventory, there are four places of articulation plus glottal articulation, and there are five manners of articulation in Indonesian. These are shown in the following table.

Table 1.4: Phonemic consonant inventory in Indonesian

		bilabial	coronal	palatal	velar	glottal
stops:	voiceless	p	t	č	k	ʔ
	voiced	b	d	ǰ	g	
nasals:		m	n	ɲ	ŋ	
fricatives:			s			h
liquids:			l, r			
glides:		w		j		

The Indonesian /t/ has been described to be produced with the tongue tip against the upper teeth and /d/ with the tongue tip against the alveolar ridge (Alieva et al., 1972, as cited in Adelaar, 1983). Adelaar supports these observations based on the co-occurrence restrictions of consonants in the earlier stage of Malay: while non-coronal stops tend not to co-occur within a stem indigenous to Malay unless they are identical in all features, /t/ and /d/ do not seem to be subjected to this restriction. In Indonesian, there are many indigenous stems of the forms dVtV(C) and tVdV(C). Adelaar suggests that these sequences are allowed because of the different place of articulation: /t/ is dental and /d/ is alveolar.

Stops in Indonesian are characterized as either voiceless or voiced, unlike Javanese stops that are all voiceless. Impressionistically, when a Javanese/Indonesian bilingual speaks Indonesian, one can hear that there is a difference in the "voice quality", relative to other non-Javanese speakers. This voice quality sounds very "Javanese" to the ears of non-Javanese speakers. The source of this impression seems to come from the fact that, among others, in the sound inventory of Indonesian and many other languages in Indonesia like Sundanese, Toba Batak, Buginese, etc., stops are either voiced or voiceless, while in Javanese, they are either breathy or clear (Fagan, 1988; Hayward, 1995; Adisasmito-Smith, 1999a), as discussed above. This is a case of language interference where a sound pattern in Indonesian is systematically substituted for by a sound pattern in Javanese.

To date, no systematic study of this influence has been carried out. The results of such a study would show the extent to which the impressionistic observations of the bilingual Javanese/Indonesian speakers are acoustically realized, in particular with respect to vowel alternation, voice quality, and syllable structure. The results would also show whether the effect reflects the borrowing of the phonological pattern, i.e. that the acoustic realization of a certain pattern can be attributed to a phonological pattern, rather than to a phonetic variation; or they may show that the effect is phonetic, rather than phonological. As discussed earlier, while careful listening does not necessarily invalidate the observations, an acoustic study provides us with data that would tell us whether the observed pattern is in fact phonological or phonetic in nature.

1.8 Interdependence of consonants and vowels

There are three issues focused on in this study: vowel alternation, voice quality, and syllable structure. Each of these phenomena is interdependent since the expression of one affects the patterning of the other. I briefly sketch out the ways in which consonants and vowels are interconnected in this section. See the respective chapters for detailed discussion.

First, vowel alternation in Javanese is determined by whether a following consonant (if one is present) is in coda position. Vowels are realized as lax when a consonant is in coda position, and otherwise as tense. Second, with respect to vowel quality, Javanese stops are distinguished as either breathy or clear. During the stop closure itself, there is no acoustic distinction between the two series, i.e. based on their duration and voicing (Fagan, 1988). The distinction is observable in the acoustic quality of the following vowel. Third, the syllable structure study is primarily concerned with the syllable affiliation of consonant clusters, especially those involving a homorganic nasal and a stop, in the root-medial position. In order to determine whether a consonant is in coda position, vowel alternation in Javanese can be used as a diagnostic; in addition, the acoustic duration of vowels would be shorter preceding a consonant in coda position than preceding that in an onset position (Maddieson, 1985).

While the sketch here presents only the issues for Javanese, both Indonesian and Javanese function as the test case in investigating these three issues. The acoustic patterns for Indonesian and Javanese as produced by the native speakers of the respective languages serve as the bases of comparison between the two languages.

1.9 The structure of this study

Chapter 2 presents the general methodology, including the background of the speakers, the procedure of obtaining measurements, and speech sound segmentation. In Chapter 3, I present the cases of vowel alternations in both dialects of Javanese and Indonesian. Vowels in open vs. closed root-final syllables are compared with respect to their formant values, acoustic duration, fundamental frequency, and amplitude. In Chapter 4, I present the acoustic analyses of breathy/clear stops in Javanese (of only one dialect) and voiced/voiceless ones in Indonesian. Using several acoustic measures of breathiness as a method of evaluation, such as fundamental frequency, spectral slope, F1 bandwidth, and harmonic-to-noise ratio, vowels following each contrastive pair of stops are compared. In Chapter 5, I turn to the cases of root-medial nasal + stop clusters in Javanese and Indonesian. The differences in the syllable affiliation of the clusters in these two languages are quantified with respect to the timing pattern of these clusters and that of the preceding vowel, in addition to the measurements of F1 bandwidth. In Chapters 3, 4, and 5, I also analyze the speech of the bilingual speakers of Javanese/Indonesian producing Indonesian forms, and compare their speech with that of the monolingual Indonesian speakers with respect to vowel alternations, voice quality, and syllable structure. In Chapter 6, the overall results and implications are discussed, and further studies are proposed.

CHAPTER TWO:
METHODOLOGY

In this chapter, I present the general methodology for analyzing the data, the construction of the wordlists, the recording of the data, the digitization of analyzed tokens, and the extraction of measurement values. The methodologies specific to each of the three studies in this work are presented in the respective chapters.

2.1 Wordlist construction

There are two sets of wordlists constructed for this study. One wordlist contains only Indonesian words, and another one contains only Javanese words. All of the words in the set are bisyllabic, as the majority of standard (or native) lexical root form in Indonesian and Javanese are bisyllabic (85% for Javanese (Uhlenbeck, 1978)). As much as possible, the words included in the list are real and of native origin, even though to fill the gaps in the paradigm several borrowed words and several phonotactically possible non-words are used. The words in the lists were obtained by consulting *Kamus Indonesia-Inggris* (Echols and Shadily, 1992), an Indonesian-English dictionary for the Indonesian words and several Javanese dictionaries (e.g. Horne, 1974; Pigeaud, 1982) for the Javanese ones, as well as from my own vocabulary.

The shapes of the target words are controlled, depending on the phenomenon being focused on. In Table 2.1, I present the schema of the word shapes analyzed in this study. These word shapes are illustrated with one example for each language. Target sounds are underlined. The words follow the IPA convention. Within a set of words, the consonants or the vowels surrounding the target sounds are kept the same whenever possible. This is to avoid variations in the acoustic measurements due to effects from different surrounding segments. The list of words analyzed for each study is presented in the respective chapter (i.e. vowel alternation study in Chapter 3, voice quality study in Chapter 4, and syllable structure study in Chapter 5).

Table 2.1: Schema of shapes of words for the wordlist

	Javanese (Central/Eastern)	gloss	Indonesian	gloss
(a) Vowel alternation study				
CVCV	titi	meticulous	susu	milk
CVCVC	titɪp	entrust	susut	decrease
CVCV	titi	meticulous	susu	milk
CVCVC	titɪp/tɪtɪp	entrust	susut	decrease
(b) Voice quality study				
$CVC_{b/vd}$[1]V(C)	$tap^{ɦ}ah$	courageous	padas	rock
$CVC_{c/vl}$[2]V(C)	tapah	non-word[4]	patah	broken
CVN[3]$C_{b/vd}$V(C)	$tamb^{ɦ}ah$	add	pandas	non-word[4]
$CVNC_{c/vl}$V(C)	tampah	container	pantas	suitable
(c) Syllable structure study				
CVCV(C)	sɔkɔ	pillar	sadar	aware
CVNCV(C)	sɔŋkɔ	suspect	sandar	lean on

Note:
[1]b = breathy; vd = voiced
[2]c = clear; vl = voiceless
[3]N = homorganic nasal
[4]non-word = nonsense word

For the Javanese words in part (a) of this table, two adjacent words, e.g. *titɪp*/*tɪtɪp*, indicate the different pronunciations between the Eastern and Central dialects, in that order. However, this is only the case with the set in (a), since no Eastern Javanese speakers were recorded for the sets in (b) and (c). The data set in (b) and (c) were produced by speakers recorded in the US (see § 2.2 for further discussion of the speakers). The specific sets of data that are analyzed in this study are presented in the individual relevant chapters.

For the vowel alternation study, vowels are compared in final open vs. closed syllable; in addition, to investigate vowel harmony, penultimate vowels are compared when the following (final) syllable is open vs. closed. For the voice quality study, (b), the target stop is in word-medial position; comparison is made between intervocalic cases and preceded-by-nasal cases. For the syllable structure study, (c), the durations of penultimate vowels preceding single consonant, homorganic nasal + stop, and two non-homorganic consonants are compared.

2.2 Selection of speakers and locations

The data collection in this study was carried out over two different periods of times, in two different places, in Indonesia and in the US. The speakers recorded in Indonesia are divided into three groups: the monolingual Indonesian group, the bilingual Central Javanese/ Indonesian group, and the bilingual Eastern Javanese/ Indonesian group. No monolingual Javanese speakers are included in this study. There are two reasons underlying this decision. First, in the speech of the bilingual Javanese/Indonesian speakers, Javanese is linguistically dominant; that is, Javanese is their first language, and despite using Indonesian for certain occasions (mostly formal or public contexts), Javanese is still the primary language in the daily life of these bilinguals. Second, this study focuses on the manifestation of Javanese in the Indonesian of the bilingual speakers; thus the Javanese as spoken by the bilinguals is of primary interest. In addition, there are only a few monolingual Javanese in the city, and one would have to go to more remote rural areas and study the speech of older speakers. This, however, does not imply that the study of the monolingual Javanese speakers is irrelevant. One may want to investigate the extent to which the Javanese of the monolinguals and that of the bilinguals differ, e.g. how much the patterns of Indonesian influence the Javanese of the bilinguals. This would certainly warrant the inclusion of the Javanese monolingual speakers. This is beyond the scope of the present study.

While numerous speakers were recorded, systematic analysis of a full set of data is presented here for three speakers for each group. This is due to several reasons: (1) some speakers had colds and/or a sore throat during the recording; (2) some speakers were nervous or very soft spoken during recording, rendering acoustic analyses of their speech very difficult; (3) some speakers moved out of the area when they were young and had returned there only recently, making their linguistic affiliation unclear; (4) some (bilingual) speakers perceived this study to be a test of their ability to speak ‘proper’ Indonesian, and seemed to modify their speech accordingly; (5) mixing male and female speakers in some of the acoustic analyses is not possible.

The bilingual Javanese/Indonesian speakers from Malang (East Java) are identified as EJ_m1, EJ_m2, and EJ_m3. The bilingual Javanese/ Indonesian speakers from Solo (Central Java) are identified as CJ_m1, CJ_m2, and CJ_m3. The monolingual Indonesian speakers from Jakarta are IM_m1, IM_m2, and IM_m3. For the Javanese speakers, the criteria used are: (1) place of birth; (2) place of growing up; (3) length of time in the respective city; (4) language spoken at home. The recorded data from these nine speakers are analyzed in Chapter 3 (vowel alternation study).

In order to supplement the initial study, further recordings were made in the US. The recorded data are analyzed in Chapters 4 (voice quality study) and 5 (syllable structure study). There are two groups of speakers who were recorded in the US, and each group consists of three people. The bilingual Central Javanese/Indonesian speakers are CJ_f7, CJ_m6, and CJ_m7. They are originally from the Solo/Jogjakarta areas, and have lived in the US for over 5 years. While there is a possibility that their speech may have been influenced by English, their profession as teachers of Javanese music as well as performers (as singers in and puppeteers of *wayang* shadow plays) seems to help preserve the Javanese features of their speech, including relative breathiness. Interviews were also conducted after the recording in order to judge their Javanese and Indonesian. In a previous acoustic study (Adisasmito-Smith, 1999a), Javanese tokens produced by speaker MR were compared with those produced by other Javanese speakers recorded in Solo. The results show that individual speakers, both of those recorded in Indonesia and in the US, including CJ_m6, combine different strategies to produce relative breathiness, but there is no systematic difference as a group between the speakers recorded in the US and those recorded in Indonesia.

The monolingual Indonesian speakers recorded in the US are IM_f6, IM_f7, and IM_m7. Two of the speakers (IM_f6 and IM_m7) were graduate students. Speaker IM_f7 was in the US to accompany her husband. They have lived in the US ranging from one and a half to five years. I summarize the profile of speakers in this study in Table 2.2.

Table 2.2: Speakers in this study, recorded in Java and in the US

a) in Java	monolingual	bilingual	bilingual
1. origin	Jakarta	Solo	Malang
2. language/s spoken	Indonesian	Central Javanese and Indonesian	Eastern Javanese and Indonesian
3. numbers recorded	11	11	13
4. numbers presented in this study	3	3	3
b) in the US	**monolingual**	**bilingual**	
1. origin	Jakarta	Solo/Jogjakarta	
2. language/s spoken	Indonesian, English	Central Javanese, Indonesian, English	
3. numbers recorded	3	4	
4. numbers presented in this study	3	3	

As for the locations for recording in Java, the cities of Solo and Malang were chosen, due to their unique characteristics with respect to cultural identity and geographic location. Solo is an ideal location for the purpose of this research, since most Javanese from this city are proud to be Javanese; consequently it is most likely that when they speak Indonesian, they would not try to sound like Indonesian speakers from Jakarta, or from other places. Geographically, it is located centrally with respect to the distance from other centers of major language communities, or other 'major' Javanese dialects (e.g. the Tegal Javanese to the northwest (Grimes, 1996), or the Purwokerto/ Banjarnegara Javanese[3] to the west).

Malang is similar to Solo with respect to being centrally located, and it too is a fair distance from other 'major' language communities. In areas to the north and northeast, Madurese is spoken; to the east, in the areas of Banyuwangi and Bali, Osing and Balinese are spoken; to the west, Central Javanese is spoken. With respect to cultural identity, Javanese speakers from Malang seem to be proud of their own language in the sense that they do not seem to consider the Javanese dialects in Surabaya, Madiun, or Solo/Jogjakarta (i.e. all other major urban areas) to be better than their own dialect.

The monolingual speakers of Indonesian were all born and raised in Jakarta, and currently reside there. Those recorded in the US were also

[3] No systematic study of this particular dialect can be found. Impressionistically, this dialect has heavy influence from Sundanese, most notably the absence of vowel alternation due to syllable structure in final position, which is typical in Javanese. The stops in this dialect may be contrastive with respect to voicing, rather than breathiness. More detailed phonetic and phonological study would be an interesting area of further research.

born and raised in Jakarta, and have lived there continuously prior to studying in the US.

2.3 Data recording

Recording sessions in Java and in the US were carried out in quiet places, such as an inner room in a house, a broadcasting studio in a radio station, or a soundproof room. Recordings were made on analog tapes. In Java, a portable SONY cassette recorder and a hand-held microphone were used. During the recording, the microphone, mounted on a microphone stand, was placed on the table in front of the speaker, at a distance of about 8-10 inches from the mouth and about 45 degree to the side. In the US, recordings were carried out using a Marantz PMD222 portable cassette recorder with an AKG D310 head-mounted microphone.[4]

Before the recording began, the speakers were given instructions about the recording. They were asked to look through the wordlist, presented in standard Indonesian and Javanese orthography (i.e. in Roman alphabets), and to practice reading a few words embedded in the frame sentence. They were informed that there were nonsense words in the wordlist. The wordlists were read at a comfortable reading rate. During the recording, speakers were presented with one flash card at a time, on which the targeted words were written. When mispronunciation occurred,

[4] Note that the use of a head-mounted microphone may reduce the acoustic record of voicing, since the signal is picked up exterior to the neck. However, as I show in the voice quality study in Chapter 4, the complete lack of voicing for the Central Javanese speakers is consistent with pilot studies and also with other previous studies.

speakers were asked to continue and to repeat the missed words three times after they have finished reading the whole wordlist.

The words in the list were read four times in a row, rather than being randomized, in order to maintain consistent intonation. All words in both languages were read embedded in a frame sentence. For the Indonesian words, the frame sentence used was *Dibaca* _____ *sekali* 'Read ____ once.' For the Javanese words, it was *Diwaca* _____ *sepisan* 'Read ____ once.' The monolingual Indonesian speakers read only the Indonesian wordlist, and the bilingual Javanese/Indonesian speakers read both the Indonesian and Javanese wordlists. Due to time constraints, both wordlists were read by the bilingual speakers in the same session with about a 10-15 minute break between the recordings of the two sets. The Javanese wordlist was read and recorded first, followed by the Indonesian wordlist.

After the recording was completed, all speakers but the first one recorded (who was interviewed before the recording) were interviewed to assess their linguistic background. For the list of questions, interviews, and summary, see Appendix A. The reason for interviewing the speakers after, rather than before the recording is to prevent speakers to modify their speech to accommodate their response to the interview questions, as was the case with the first recorded speaker. The communication with speakers was conducted in Indonesian for the monolingual Indonesian speakers, in a mix of Central Javanese (of middle register) and Indonesian with the Central Javanese speakers, and in Eastern Javanese (of low register) and Indonesian with the Eastern Javanese speakers. I am fluent in each of these languages.

2.4 Segmentation and value extraction

All acoustic analysis was conducted at the Cornell University Phonetics Lab. The recorded speech was digitized at 11,025 Hz using a SUNSPARC workstation, and was analyzed using the Waves+/ESPS.

The sounds under investigation are vowels in the initial and final syllables, and consonants in root-medial intervocalic position. To determine the beginning and end points of a sound, both waveforms and spectrograms were used to ensure accuracy. The set of the waveform, the spectrogram, and labels for the Indonesian word *padas*, shown in Figure 2.1, illustrates the procedure of segmentation.

For the vowels, their onset and offset points coincide with the onset and offset points of the second formant. The labels that are assigned to these points are *v1-on* and *v2-on* for the beginning of the first and second vowels and *v1-off* and *v2-off* for the end of these vowels.

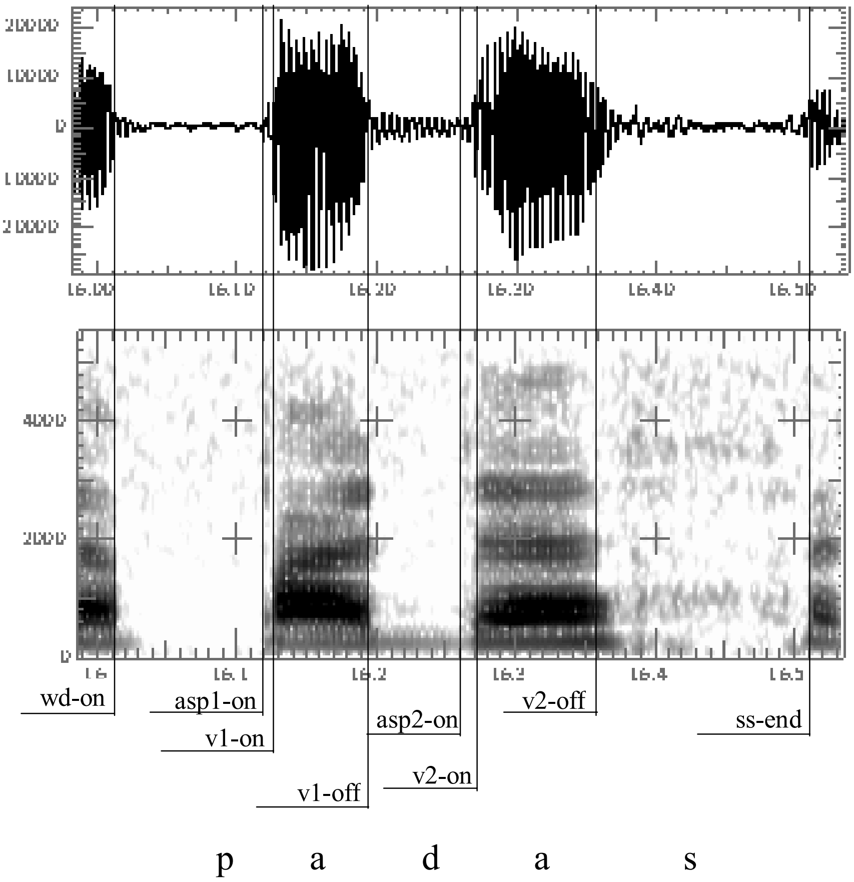


Figure 2.1: The waveform, spectrogram and labels for the segmentation of the vowels and stops in the Indonesian word *padas* ‘rock’, as produced by the monolingual Indonesian speaker IM_m7

The beginning of a stop is taken to be the point where the second formant of the preceding vowel has dissipated. No separate label is assigned to mark the beginning of a stop; rather the label marking the end of a vowel, i.e. *v1-off* or *v2-off* indicates the onset of a root-medial or a root-final consonant. Root-initial stops begin with the label *wd-on* indicating the beginning of the target word. When a stop immediately follows a nasal, the onset of the stop is taken to be the disappearance of formant structure of the nasal. The offset of a stop is taken to be the point where the burst release appears, and the label assigned is *asp1-on* for the offset of a root-initial stop and *asp2-on* for a root-medial stop. Separate labels of aspiration offer flexibility in the analysis.

The offset point of stops in the final position of the target word is labeled *wd-off*. When a target word ends with the fricative /s/, it becomes indistinguishable from the fricative /s/ at the beginning of the frame word *sekali*. The label marking the beginning point for word final /s/ is the label indicating the end of the preceding vowel (*v2-off* in Figure 2.1). The label marking the end point of /s/ which is the beginning of the initial vowel in *sekali* is *ss-end*, to denote the end of the two /s/'s.

Similar to the onset of the stops, that of nasals is the point where the second formant of the preceding vowel has dissipated; the label referring to the beginning of a nasal is thus *v1-off* or *v2-off*. This is illustrated in Figure 2.2. The offset of syllable initial nasals is the appearance of the second formant of the following vowel and marked *v1-on* or *v2-on*. In the wordlist for this study, there is no nasal occurring in word final position.

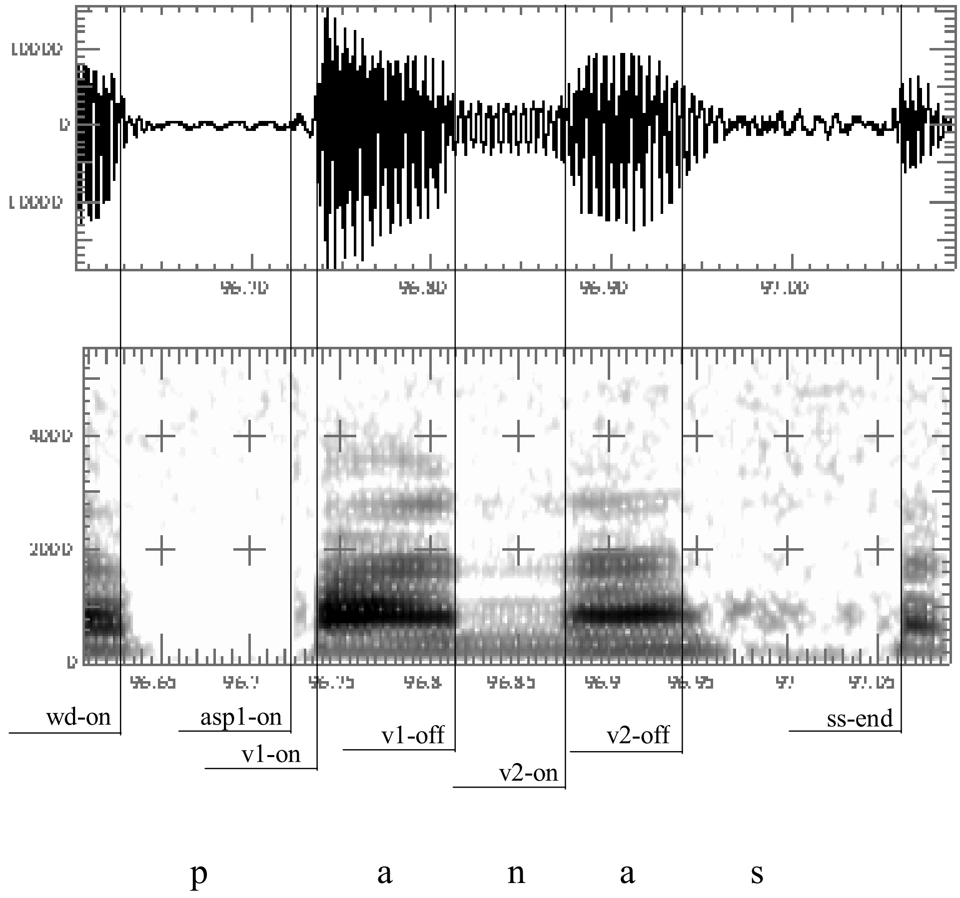


Figure 2.2 The waveform, spectrogram and labels for the segmentation of the vowels and stops in the Indonesian word *panas* ‘hot’, as produced by the monolingual Indonesian speaker IM_m7

Measurements of segments were carried out by referring to the delimiting labels. Thanks to Eric Evans and Marek Przezdziecki who created the scripts for the acoustic measurements. The results of the measurements were transferred from a SUN station to a PC and analyzed using the Microsoft Excel spreadsheet program, from which the charts in Chapters 3, 4, and 5 were derived. The data were further analyzed using the statistical software package SPSS. I turn now to the results of the three studies.

CHAPTER THREE:
THE INFLUENCE OF JAVANESE VOWEL PATTERNING ON INDONESIAN

While the vowel inventories of Javanese and Indonesian are actually not very different, one of the differences of vowels in these two languages has to do with vowel alternations, which are primarily governed by syllable structure. In both the Central and Eastern dialects of Javanese, high and mid vowels alternate in tenseness depending on whether they are in an open or a closed syllable. Similarly, mid vowels in Indonesian alternate in tenseness depending on syllable structure. Indonesian high vowels, however, have been described to alternate in tenseness by some (e.g. Macdonald and Dardjowidjojo, 1967; Lapoliwa, 1981), even though impressionistically they do not. Further, a vowel in the penultimate syllable undergoes vowel harmony in Indonesian and Javanese. In the Eastern dialect of Javanese, all penultimate vowels harmonize with the final vowel; in the Central dialect, mid and low vowels undergo vowel harmony; in Indonesian, mid vowels exhibits the phenomenon of vowel harmony. Most of these claims are based on impressionistic observations only. In this chapter, the acoustic analyses focus on the effect of syllable structure on root-final vowel, and on vowel harmony that affects vowels in the penultimate syllable in Javanese and Indonesian. Comparisons are made between speakers of the Central and the Eastern dialects of Javanese and between these bilingual speakers of Javanese/Indonesian and monolingual speakers of Indonesian.

To date, there are only a few phonetic and phonological studies of vowels in Indonesian and Javanese. There is no systematic acoustic study on Javanese vowels, and the present study is, to my knowledge, the first one conducted based on speakers from the Central and Eastern Java regions. There are two earlier acoustic studies of Indonesian vowels, carried out by van Zanten (1989) and Adisasmito-Smith (1999b). In both studies, the vowel system in the bilingual speakers' language background is found to influence the production of Indonesian vowels, especially with respect to the formant structure. Both studies compare monolingual Indonesian and bilingual Javanese/Indonesian speakers. In addition, van Zanten compares speakers who are bilingual Batak/Indonesian and bilingual Sundanese/Indonesian. Formant structure and durations of the vowels by these different speakers were investigated in these two studies.

As discussed in Chapter 1, phonetic differences may be due to phonological differences, but they may also be the result of phonetic environment (i.e. coarticulation effect). For the case of vowel alternations in Indonesian, van Zanten (1989) and Adisasmito-Smith (1999b) find that high vowels in word-final CVC syllable undergo lowering for both the monolingual Indonesian and the bilingual Javanese/Indonesian speakers. For the monolingual speakers, a lowered vowel in a word-final CVC syllable is impressionistically similar to the same (tense) vowel in a word-final CV syllable. On the other hand, a lowered vowel in a word-final CVC syllable for the bilingual speakers is impressionistically different from the same (tense) vowel in a word-final CV syllable. To account for the differences observed, I argue that the acoustic lowering of the high vowels in a final CVC syllable in Indonesian by the bilingual Javanese/Indonesian speakers is the realization of phonological vowel lowering of Javanese in the Indonesian of these speakers; it is the acoustic realization of vowel alternation in Javanese, as the source of influence on the Indonesian of the bilingual speakers. Thus, the lowering here would be categorical. Further, I argue that the acoustic lowering of high vowels in final CVC syllable by the monolingual Indonesian speakers is due to the effect of the following consonant; thus the differences here are due to phonetic environment (coarticulation), and consequently are gradient in nature (Adisasmito-Smith, 1999b).

As briefly mentioned earlier, penultimate vowels in Javanese and Indonesian undergo vowel harmony, whereby penultimate vowels harmonize with final vowels in $CV_1CV_2(C)$ roots (where $V_1=V_2$). Parallel to the alternation of vowels in a final syllable, the tense/lax vowel harmony observed in Javanese and Indonesian may be phonological or phonetic. If vowel laxing is due to coarticulation (i.e. the effect of a neighboring vowel), we would expect the effect to be gradient. Acoustic studies on vowel-to-vowel coarticulation in different languages show that a vowel in VCV sequences may coarticulate with a preceding or a following vowel (e.g. Ohman (1966); Magen (1984); Manuel and Krakow (1984); Recasens (1987); Manuel (1990); Choi and Keating (1991)). For examples, a vowel tends to have higher F2 when preceded (carryover effect) or followed (anticipatory effect) by a high front vowel (e.g. /i/), and conversely, a vowel tends to have lower F2 in the environment of a low vowel like /a/. If, however, vowel harmony in the two languages examined here is a phonological process, then the difference between the tense vowels vs. the lax ones would be categorical, regardless of vowel inventory, stress, or the intervening consonant.

The organization of this chapter is as follows. In § 3.1, I discuss the phonological facts that motivate an acoustic investigation. In § 3.2, I present the methodology. The results are presented in § 3.3 through § 3.6, and I discuss the overall results briefly in § 3.7.

3.1 Phonological patterning of vowels in Indonesian and Javanese

Indonesian vowels have been the subject of discussion in several works (Lapoliwa, 1981; Adisasmito, 1993; Cohn, 1989; Cohn and McCarthy, 1998, to name a few). Lapoliwa discusses vowel alternation based on position in the word and stress. Adisasmito argues that some schwas in Indonesian are underlying, while other schwas are derived, depending on syllable structure and the origin of the words. Cohn (1989) and Cohn and McCarthy (1998) provide an account of the phonotactics of Indonesian vowels (schwa, in particular) with respect to word structure and stress. These studies are consistent with the impressionistic observations, but do not allow us to address the more specific questions posed here.

There are a number of phonological studies of Javanese vowels. With respect to its vowel inventory, Javanese is claimed to have six phonemic vowels, of which five have two surface realizations (e.g. Uhlenbeck, 1978). However, it has also been claimed to have eight phonemic vowels (e.g. Samsuri, 1958, Sumukti, 1971), where [ɛ] and [ɔ] are considered phonemic, rather than allophones of /e/ and /o/ respectively. While many agree with Uhlenbeck's view (e.g. Dudas, 1976; Yallop, 1982; the present study), some support Samsuri's view, such as Ogloblin (1993). Other more recent works on Javanese vowels, particularly with respect to their phonological alternations and the role of morpheme structure, are those by Archangeli (1998), Benua (1996), and Hargus (1993).

In Table 3.1, I present the vowel inventories in both dialects of Javanese and in Indonesian (see also Chapter 1). As mentioned earlier, both languages have similar vowel inventories. Following Uhlenbeck's (1978) analysis of Javanese, there are six vowels in each of the inventories. There are also several diphthongs in Indonesian, but none in Javanese, and therefore these are excluded from this study. The vowel inventories are presented in Table 3.1.

Table 3.1: Phonemic vowel inventory of Javanese and Indonesian

Javanese			
high	i		u
mid	e	ə	o
low		a	

Indonesian			
high	i		u
mid	e	ə	o
low		a	

I turn now to a more detailed comparison of the tense-lax alternation in the Eastern and Central dialects of Javanese and in Indonesian. First, I present the case in Javanese.

In both dialects of Javanese, vowels alternate in being tense or lax depending on syllable structure. Examples in (1) illustrate this. Note that in all the data for Javanese in this study, I represent the breathy stops as voiceless stops followed by a breathy release, e.g. [$p^{ɦ}$] for the bilabial breathy stop. This notation is in accordance with the acoustic realization of these stops (see, e.g., Adisasmito-Smith, 1999a; and Chapter 4 of this dissertation).

(1) *Vowel alternation in final syllables in Javanese*

(a) CVCV words			(b) CVCVC words		
/pʱuri/	[pʱur*ɪ*]	'back'	/pʱurik/	[pʱur*ɪ*ʔ]	'spotty'
/kaku/	[kak*u*]	'stiff'	/kakuŋ/	[kak*ʊ*ŋ]	'male'
/kere/	[ker*e*]	'homeless'	/kerek/	[kɛr*ɛ*ʔ]	'raise a flag'
/solo/	[sol*o*]	'k.o. tree'	/čoloŋ/	[čɔl*ɔ*ŋ]	'steal'
/sutʱa/	[sutʱ*ɔ*]	'decrease'	/utʱan/	[utʱ*a*n]	'rain'
			/səpət/	[səp*ə*t]	'tart'

In a root-final open syllable, vowels are impressionistically tense, as shown in (1a), while in a closed syllable they are lax, as shown in (1b), except for the low vowel /a/. Impressionistically, the high vowel [ɪ] in closed final syllables is similar to the mid vowel [e] in open syllables. The perceived similarities are evident in the ways in which Javanese words are transcribed by linguists (e.g. Sumukti, 1971; Suharno, 1982; Benua, 1996) and in the ways in which they are orthographically represented by Javanese (e.g. in personal letters, electronic mail communications, etc).[5] In these cases, high vowels in final CVC syllables are represented as "e" and "o", as shown in the examples in (2).

[5] The Javanese language has a syllabary writing alphabet based on Devanagari. The number of Javanese who are fluent in writing in this alphabet are quite small; many Javanese speakers use Javanese in spoken communication and switch to Indonesian when writing. The observations of how Javanese sounds are orthographically represented are based on cases where the writing communication is carried out in Javanese, using the Roman alphabets.

(2) *Writing of Javanese high vowels in final CVC syllables*

Word	Gloss	Orthographic representation
/mulih/	‘go home’	muleh
/salin/	‘change clothes’	salen
/karuŋ/	‘sack’	karong
/parut/	‘grate’	parot

The realization of the low vowel /a/, as shown in (1), is interesting in that when it is in a word-final open syllable, as in *sut^{ɦ}a* ‘decrease’, its acoustic realization is impressionistically similar to the realization of the mid vowel /o/ in a final closed syllable, as in [čɔlɔŋ] ‘steal’. Given this impressionistic similarity, in this study I represent /a/ in final open syllables as [ɔ].[6] In a closed syllable, the low vowel surfaces as [a], as in [ut^{ɦ}an]. In cases where the root-final /a/ is not in word-final position, e.g. when a suffix follows the root, /a/ surfaces as [a], as in /sut^{ɦ}a + ne/ → [sut^{ɦ}ane] ‘the decrease’.

Note that the central vowel /ə/ is excluded from the discussion since impressionistically there is no apparent alternation whether it is in an open penultimate syllable: [s$\underline{\text{ə}}$pət] ‘tart’, or a closed penultimate: [s$\underline{\text{ə}}$ksi] ‘witness’ or a final one: [səp$\underline{\text{ə}}$t] ‘tart’. No schwa occurs in an open final syllable.

When the underlying vowels in the penultimate and final syllables are the same, they undergo vowel harmony, a process whereby a vowel

[6] Note that several authors have used a different symbol to represent it: [ɒ]. (e.g. Benua, 1996; Horne, 1974). It is not clear whether this symbol is intended to indicate that the impressionistic realizations of /a/ in the open final syllable and of /o/ in the closed final syllable are different, or to indicate different underlying vowels which are impressionistically similar: [ɔ].

assimilates some or all of its features to another vowel preceding or following it. This is illustrated in (3a). This pattern also applies to different vowels that share the same height, as illustrated in (3b).

(3) *Vowel harmony in Central and Eastern Javanese*

		Eastern Javanese	Central Javanese	gloss
a) **V1 = V2 cases**				
i. CVCV	/sisi/	[s*i*si]	[s*i*si]	'blow one's nose'
	/loro/	[l*o*ro]	[l*o*ro]	'two'
	/pala/	[p*ɔ*lɔ]	[p*ɔ*lɔ]	'nutmeg'
ii. CVCVC	/sisiʔ/	[s*ɪ*sɪʔ]	[s*i*sɪʔ]	'fish scale'
	/lorot/	[l*ɔ*rɔt]	[l*ɔ*rɔt]	'slide down'
	/palaŋ/	[p*a*laŋ]	[p*a*laŋ]	'gate'
b) **V1 ≠ V2 cases**				
i. CVCV	/ip^{ɦ}u/	[*i*p^{ɦ}u]	[*i*p^{ɦ}u]	'mother'
	/tip^{ɦ}a/	[t*i*p^{ɦ}ɔ]	[t*i*p^{ɦ}ɔ]	'fall'
	/sore/	[s*o*re]	[s*o*re]	'afternoon'
	/t^{ɦ}oŋa/	[t^{ɦ}*o*ŋɔ]	[t^{ɦ}*o*ŋɔ]	'pray'
ii. CVCVC	/misuh/	[m*ɪ*sʊh]	[m*i*sʊh]	'swear'
	/kit^{ɦ}al/	[k*i*t^{ɦ}al]	[k*i*t^{ɦ}al]	'left-handed'
	/koreʔ/	[k*ɔ*rɛʔ]	[k*o*rɛʔ]	'match'
	/omah/	[*ɔ*mah]	[*o*mah]	'house'

The examples in (3a.i) show that the high and mid vowels in the final syllable of a CVCV word is realized as tense, and the low vowel /a/

is realized as [ɔ]. The penultimate vowel is also realized as tense, e.g. [*loro*] 'two'. This is the case for both Javanese dialects. However, these two dialects diverge in the CVCVC case. As shown in (3a.ii), in the Central dialect, the vowel in the final syllable is realized as lax, and the penultimate vowel remains tense when it is a high vowel: [*sisɪʔ*] 'fish scale'; in the Eastern dialect, both the penultimate and the final vowels are lax: [*sɪsɪʔ*]. For the mid and low vowels, the two dialects share the same pattern. For the mid vowels, the penultimate vowel is realized as lax: [*lɔrɔt*] 'slide'. The low vowel /a/ is realized as [a] in both the penultimate and final syllables.

Parallel to the cases in (3a.i), the cases in (3b.i) show that both vowels in the penultimate and final syllables in a CVCV word form are realized as tense in both dialects, when the vowels are different but share the same height. The cases in (3b.ii) illustrate the differences between the two dialects in that in a CVCVC word form, the penultimate vowel remains tense in the Central dialect: e.g. [korɛʔ] 'match', but it is realized as lax in the Eastern dialect: [kɔrɛʔ]. In addition, the two dialects differ in cases where the penultimate vowel is mid and the final vowel is low, e.g. in /omah/. In the Central dialect, the mid vowel remains tense, [o], but in the Eastern dialect, it is realized as lax: [ɔ]. This would indicate that the trigger of vowel harmony is not just the identity of the vowel (i.e. same vowel), but further the height of the vowel: /a/ is a low vowel, and it triggers the lowering of the preceding non-high vowels. For further detailed discussion of the phonological aspects of vowel alternations and vowel harmony in Javanese (particularly for the Central dialect), see Dudas (1976) and Yallop (1982). The focus of the present study is cases where underlying vowels in the penultimate and final syllables are the same, as illustrated in (3a).

In Indonesian the situation is somewhat different. Impressionistically, the high vowels are tense in either an open or a closed final syllable, e.g. [siku] ‘elbow’ and [tikus] ‘mouse’, and high vowels in the penultimate syllable also remain tense, e.g. [gigi]‘tooth’ and [gigit]‘bite’. This is illustrated in (4).

(4) *Vowel alternation in final syllables in Indonesian*

(a) CVCV̲ words			(b) CVCV̲C words		
/siku/	[sik*u*]	‘elbow’	/tikus/	[tik*u*s]	‘mouse’
/gigi/	[gig*i*]	‘tooth’	/gigit/	[gig*ɨ*t]	‘bite’
/sate/	[sat*e*]	‘kabob’	/luber/	[lub*ɛ*r]	‘overflow’
/toko/	[tok*o*]	‘shop’	/toloŋ/	[tɔl*ɔ*ŋ]	‘help’
/bila/	[bil*a*]	‘when’	/bilaŋ/	[bil*a*ŋ]	‘count’
			/čəpət/	[čəp*ə*t]	‘fast (informal)’

Similar to the Javanese case, when a mid vowel is in an open final syllable, it is realized as tense in Indonesian, as in [sate] ‘kabob’. When the final syllable is closed, the mid vowel is realized as lax, as in [lubɛr] ‘overflow’. Impressionistically, the low vowel is realized as [a] in an open or in a closed final syllable: [bila] ‘when’ vs. [bilaŋ] ‘count’.

As with the case in Javanese, the central vowel /ə/ in Indonesian is excluded from the discussion, for the same reason. It is impressionistically similar when in open penultimate: [čə̲pət] ‘fast (informal)’, closed penultimate: [tə̲rka] ‘guess’, and closed final syllables: [čəpə̲t] ‘fast (informal)’. No schwa occurs in an open final syllable (except in a few borrowed Dutch words, like [bədində] 'servant'), and occurs only in closed final syllables in informal speech.

With respect to vowel harmony in Indonesian, when the penultimate and final vowels in CVCV words are the same, both vowels are realized as tense, e.g. [kiri] 'left', as shown in (5a.i). This is the case for vowels of all height. In CVCVC words, the high vowels in the penultimate and final syllables are impressionistically also realized as tense, e.g. [kirim] 'send', as shown in (5a.ii). For the mid-vowel case, they are realized as lax, e.g. [pɔtɔŋ] 'cut'. Both the low vowels in [lamar] 'propose' are impressionistically similar.

(5) *Vowel harmony in Indonesian*

a) **V1 = V2 cases**			gloss
i. CVCV	/kiri/	[kiri]	'left'
	/toko/	[toko]	'store'
	/lama/	[lama]	'long time'
ii. CVCVC	/kirim/	[kirim]	'send'
	/potoŋ/	[pɔtɔŋ]	'cut'
	/lamar/	[lamar]	'propose'
b) **V1 ≠ V2 cases**			
i. CVCV	/tuli/	[tuli]	'deaf'
	/sore/	[sore]	'late afternoon'
	/dia/	[di^{y}a]	'he/she'
	/čoba/	[čoba] or [čɔba]	'try'

ii. CVCVC	/tulis/	[tulis]	'write'
	/gores/	[gɔrɛs]	'scratch'
	/diam/	[di^{y}am]	'silent'
	/sopan/	[sopan] or [sɔpan]	'polite'

When the vowels in the penultimate and the final syllables are different, they are realized as tense in CVCV word forms, as shown in (5b.i). Note that impressionistically, both [čoba] and [čɔba] do occur. In CVCVC word forms, when the vowels are high, they are realized as tense: e.g. [tulis] 'write'. When both vowels are mid, they are realized as lax: e.g. [gɔrɛs] 'scratch'. In the case where the final vowel is low and the penultimate vowel is high, the latter is realized as tense. However, when the penultimate vowel is a mid vowel, it is impressionistically realized as either tense or lax: [sopan] or [sɔpan] 'polite'. Similar to the case with the lowering of the penultimate mid vowels when followed by a low vowel in Eastern Javanese, this lowering in Indonesian may be a case of height harmony for non-high vowels when followed by a low vowel.

Table 3.2 summarizes the patterning of vowels in Javanese of both dialects and in Indonesian with respect to tense/lax alternation for final vowels and vowel harmony for penultimate vowels.

Table 3.2: Tense/lax alternation of final vowels and harmony of penultimate vowels in the Eastern and Central dialects of Javanese and in Indonesian

	Final position Tense/lax alternation			Penultimate position[7] Vowel harmony		
CV	high	mid	low	high	mid	low
Eastern Javanese	-	-	√	√	√	√
Central Javanese	-	-	√	-	√	√
Indonesian	-	-	-	-	√	-
CVC	high	mid	low	high	mid	low
Eastern Javanese	√	√	-	-	-	-
Central Javanese	√	√	-	-	-	-
Indonesian	-	√	-	-	-	-

Consider now cases involving bilingual speakers, where certain patterns in one language may manifest themselves in the other. For the bilingual Indonesian/Javanese speakers, if the Indonesian sound pattern prevails in their speech, then it would be observable in their Javanese; on the other hand, if the Javanese sound pattern wins out instead, then it would appear in their Indonesian. Impressionistically, the latter is the

[7] Recall that the trigger for vowel harmony is the shape (and thus, the realization of the vowel) of the final syllable. For Javanese, final CVC syllables affect the high and mid vowels and final CV syllables affect the low vowel.

case with the Javanese bilingual speakers. In the set of examples in (6), I present a list of Indonesian words and their observable surface pattern based on careful listening, for the bilingual Javanese/Indonesian speakers of both dialects of Javanese and for the monolingual Indonesian speakers. Vowels that are expected to be different for the different speaker groups are in italic.

(6) *Indonesian for the bilingual and monolingual speakers*

	Bilingual Eastern Javanese	Bilingual Central Javanese	Monolingual Indonesian	Gloss
a. high vowels:				
sisi	[sisi]	[sisi]	[sisi]	‘side’
susu	[susu]	[susu]	[susu]	‘milk’
sisir	[s*ɪ*s*ɪ*r]	[s*i*s*ɪ*r]	[s*i*s*i*r]	‘comb’
susul	[s*ʊ*s*ʊ*l]	[s*u*s*ʊ*l]	[s*u*s*u*l]	‘go after’
b. mid vowels:				
lele	[lele]	[lele]	[lele]	‘catfish’
soto	[soto]	[soto]	[soto]	‘k.o. soup’
seret	[sɛrɛt]	[sɛrɛt]	[sɛrɛt]	‘drag’
sorot	[sɔrɔt]	[sɔrɔt]	[sɔrɔt]	‘shine’
c. low vowels:				
bara	[p^{ɦ}ara]	[p^{ɦ}ara]	[bara]	‘amber’
barat	[p^{ɦ}arat]	[p^{ɦ}arat]	[barat]	‘west’

As shown in the data set in (6), impressionistically the Indonesian high vowels surface as tense in a final open syllable, for the bilingual

Javanese/Indonesian and the monolingual Indonesian speakers. In a final closed syllable, they are impressionistically lax for the bilingual speakers, but tense for monolingual speakers. The mid vowels are tense in a final open syllable and are lax in a final closed syllable, for the bilingual and the monolingual speakers. The low vowel /a/ in final open and final closed syllables is realized as [a] for the monolingual speakers, and for the bilingual speakers as well, suggesting that the Javanese alternation for /a/ in final syllables is not carried over.

With respect to vowel harmony that applies to the penultimate syllable, the high vowels are realized as tense when the final syllable is open, for all speakers. They are realized as tense when the final syllable is closed for the bilingual Central Javanese/Indonesian and the monolingual speakers, and as lax for the bilingual Eastern Javanese/ Indonesian speakers. This being the case, it means that the vowel pattern of Javanese prevails in the Indonesian of the bilingual speakers, with respect to tense/lax alternation and vowel harmony.

For the mid and low vowels, their surface pattern is impressionistically similar with respect to tense/lax alternation and vowel harmony for all three groups of speakers. Mid vowels in penultimate syllable are realized as tense when the final syllable is open, and as lax when the final syllable is closed. The low vowel /a/ in the penultimate syllable is realized as [a] for the bilingual and the monolingual speakers, whether the final syllable is open or closed.

The observations of the patterns shown in the examples in (1-5) are based on careful listening. However, to really understand the extent of their effects and whether this is due to phonetic or phonological processes, I have undertaken an instrumental study presented in this chapter. Focusing on cases where the penultimate and the final vowels are the same, we expect to see that the acoustic patterns of these vowels undergoing vowel alternation and vowel harmony would reflect their surface patterns based on impressionistic observations. I turn now to the methodology of obtaining the values for the acoustic study.

3.2 Methodology

There are nine subjects whose speech is analyzed in this study: three monolingual Indonesian speakers (IM_m1, IM_m2, IM_m3), three bilingual Central Javanese/Indonesian speakers (CJ_m1, CJ_m2, CJ_m3), and three bilingual Eastern Javanese/Indonesian speakers (EJ_m1, EJ_m2, EJ_m3). Even though female speakers were also recorded in this study, only the vowels produced by the male speakers are analyzed and presented here. The reason is because male and female speakers usually have different ranges of fundamental frequency (F0) due to the different length of the vocal cords. Male speakers tend to have longer vocal cords, and consequently tend to have lower F0 (see, e.g., Lieberman and Blumstein, 1993). Female speakers tend to have shorter vocal cords and thus tend to have a higher F0. An inevitable consequence of this inherent difference between male and female speakers is that vowels produced by female speakers, especially vowels with low first formant frequency (e.g. [i], [e], etc.) are much harder to analyze. The relatively higher F0 of female speakers often overlap with the low first formant frequency, such that it is difficult to identify them. Additionally, the different ranges of F0 for female vs. male speakers (180-400 Hz for female speakers and 80-200

Hz for male speakers (see, e.g., ‘t Hart, et al., 1990; Ladefoged, 2001)) would make F0 comparison across gender less informative.

As mentioned earlier in Chapter 2, there are two sets of words that were read by the bilingual speakers, a Javanese and an Indonesian wordlists. The monolingual speakers were presented with the Indonesian wordlist. The words analyzed in this chapter are listed in Table 3.3.

Table 3.3: Javanese and Indonesian words for vowel analyses

Javanese		Indonesian	
titi	‘meticulous’	sisi	‘side’
titip	‘entrust’	sisip	‘slip’
tete*		sese*	
tetes	‘drip’	seset	‘scrape’
rata	‘smooth’	sasa	‘MSG brand’
tatap	‘bump’	sasar	‘lost’
soto	‘k.o. soup’	soso*	
sorot	‘beam’	sorot	‘beam’
susu	‘milk’	susu	‘milk’
susut	‘decrease’	susut	‘decrease’

*Nonsense words

Each word was read at least four times by each speaker. The number of tokens analyzed is 360 (9 speakers x 10 tokens x 4 repetitions) for Indonesian, and 240 (6 speakers x 10 tokens x 4 repetitions) for Javanese.

Acoustic analyses of the tokens were done using XWaves+. A set of labels, which delimits a target segment, is used to extract values for the acoustic measurements. The beginning of penultimate vowels is marked with the label *v1-on* and the end with the label *v1-off*. The final vowels are marked with *v2-on* and *v2-off*. The values extracted were statistically analyzed using the SPSS 10 statistic package. The values for F1/F2 were analyzed using the Multivariate ANOVA, and the values for the durations, fundamental frequency, and amplitude were analyzed using One-Way ANOVA. $P < .05$ is taken to be statistically significant.

There are four acoustic measurements carried out in the vowel alternation study: (a) vowel formants, (b) vowel durations, (c) vowel fundamental frequency, and (d) vowel amplitude. The relevance of each of these measurements is discussed in the following paragraphs.

To compare vowels with respect to their relative position in the acoustic space (or vowel quality), we took the values of the first (F1) and second (F2) formants which were obtained by performing LPC analyses. As an example, Figure 3.1(a) shows the waveform and spectrogram of the Javanese word *tetes* 'drip' and a set of labels delimiting the vowels. The LPC analyses were carried out using the built-in Xspectrum software, which computes the frequency of formant peaks and represents them in a spectral graph (shown in Figure 3.1(b)). The frequency of the first formant peak is the F1 value and the frequency of the second formant peak is the F2 value. The position at which the values were obtained was at the mid point between the beginning and end points of the vowel. The formant peaks were calculated using a 25 ms Hamming window.

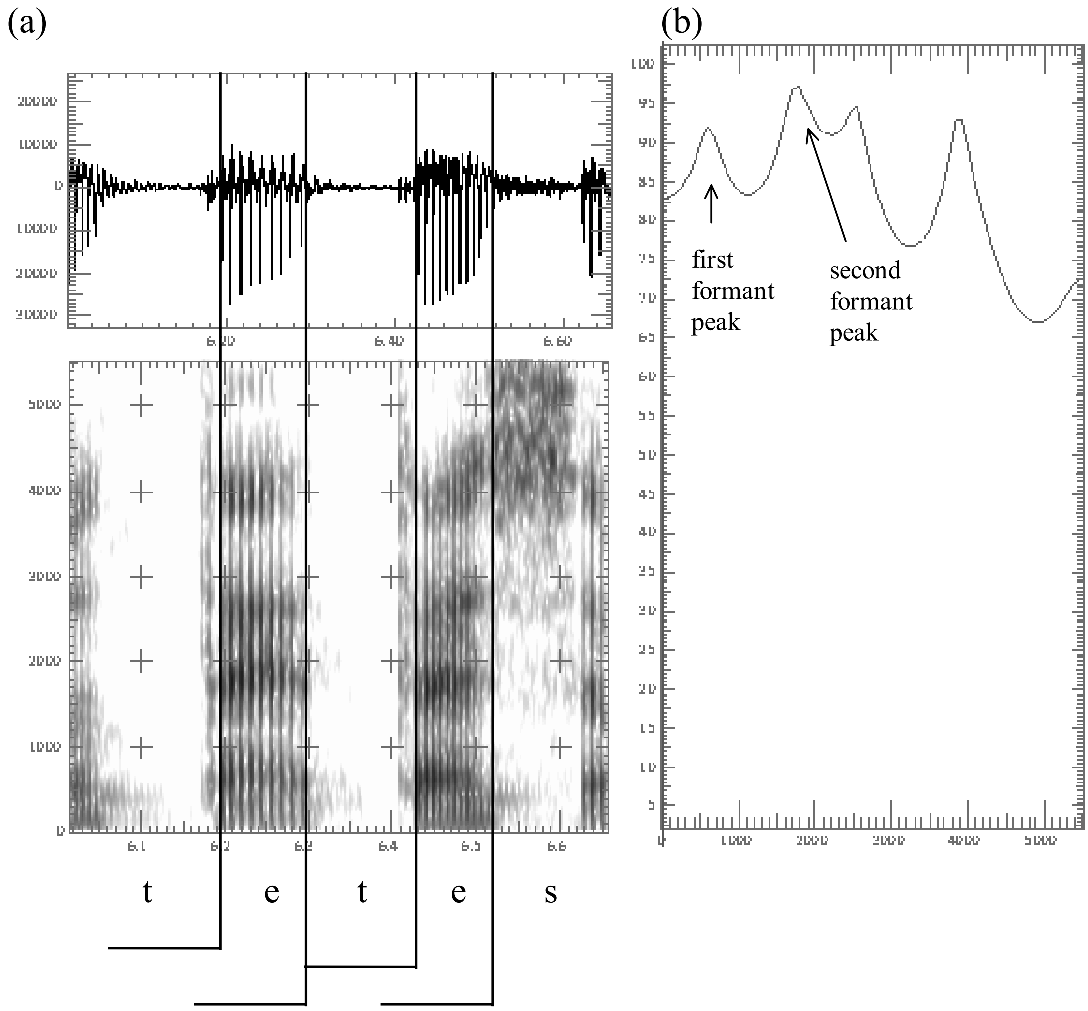


Figure 3.1: (a) Waveform and spectrogram of the Javanese word *tetes* 'drip', and (b) spectral representation of the penultimate vowel

The coordination of the F1 and F2 frequencies is associated with the height, backness, and rounding of a vowel. The correspondence between the F1 values and vowel height is inverse: high vowels have the lowest F1 values and the low vowels the highest. With respect to the second formant, high F2 values indicate front unrounded vowels and low values indicate back rounded ones. The coordination of the F1 and F2 frequencies is illustrated in the set of spectrograms in Figure 3.2.

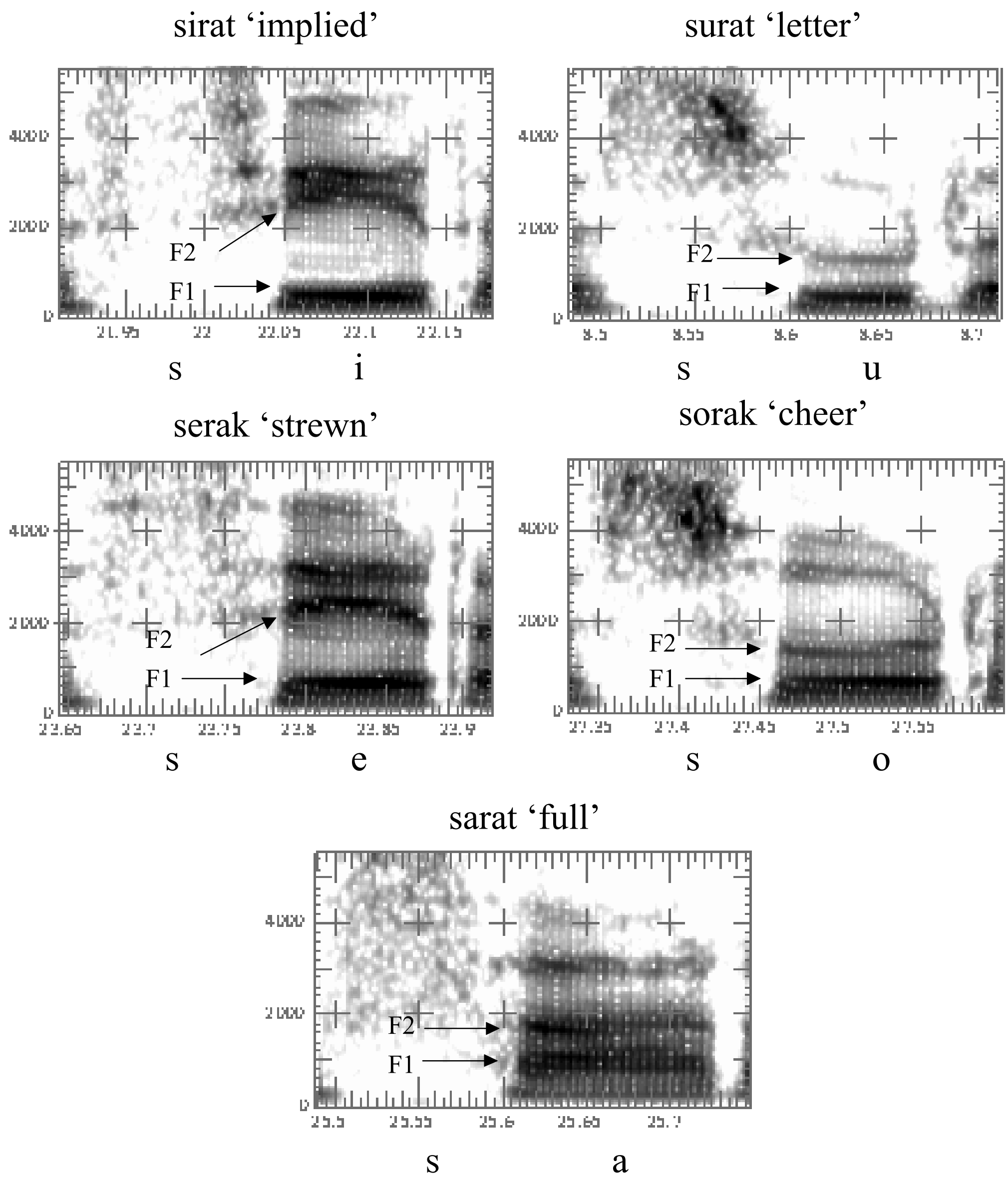


Figure 3.2: Spectrograms of vowels [i, e, a, o, u] in penultimate open syllables of Indonesian words by a bilingual Javanese/Indonesian speaker (NAS)

In the study of vowel alternation here, this correlation is used to determine the relative position of centralized vowels with their non-centralized counterparts in the acoustic space. The schema in Figure 3.3 shows an "idealized" relative position of vowels.

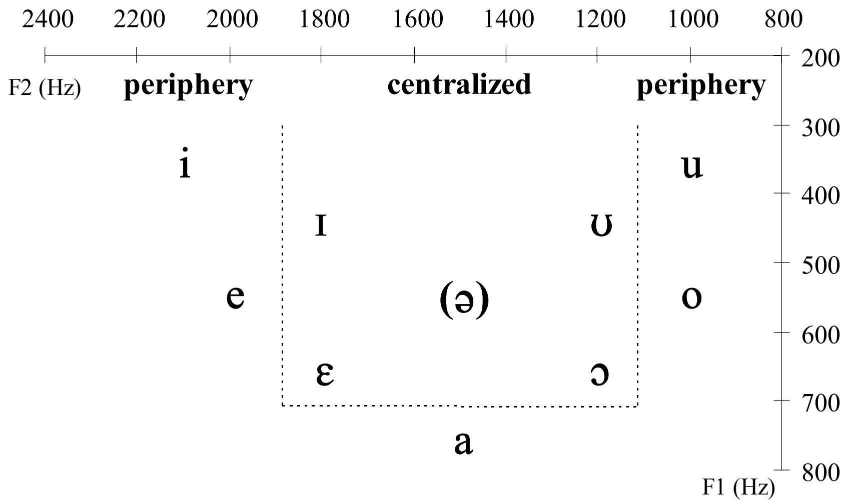


Figure 3.3: Schema of an "idealized" acoustic vowel space for tense (peripheral) vs. lax (centralized) vowels

If the relative position of the vowels and their allophones of the bilingual Javanese/Indonesian speakers concur with the expected pattern, whereby the tense vowels are in the periphery and the lax ones are closer to the center, we would expect to see the acoustic space of these vowels to be similar to the ones shown in the schema above. As mentioned earlier, the central vowel /ə/ is excluded from this study, since impressionistically it does not alternate whether it is in an open penultimate syllable, or in a closed penultimate or final one.

The measurements of vowel duration are taken as the distance between the two labels delimiting a vowel segment. The durations of vowels in open vs. closed final syllables are compared. It has been found in many languages (e.g. Maddieson, 1985) that the duration of vowels in a closed syllable is shorter than in an open syllable. On the one hand, we may predict that, for the Javanese and Indonesian vowels, their durations in open vs. closed syllables would follow this tendency. On the other hand, it has also been found that two vowels with similar F1 and F2 values, but with the duration of one of which is much shorter than the other, may be impressionistically perceived as two different vowels (e.g. in Madurese (Cohn and Lockwood, 1994)). With respect to this tendency, there are several possibilities as to what we may find in the Javanese and Indonesian vowels as produced by the bilingual speakers. One possibility is that the F1 and F2 values of a vowel in the open vs. closed syllables are similar and their durations are different. Another possibility is that its F1 and F2 values are different and their durations are different. Or it may be that the F1 and F2 values are different and their durations are similar.

As previously discussed, acoustic differences may or may not be phonologically relevant. Whether or not an acoustic effect is phonologically relevant may be language specific. Thus, some of the acoustic factors measured in this vowel alternation study may be phonologically relevant, while some others may be phonetic in nature. With respect to vowel duration, the acoustic duration of a vowel in a language where the length of a sound unit is contrastive (e.g. a language with long and short vowels), acoustic duration would be phonologically meaningful. In either Javanese or Indonesian, there is no contrast between long and short vowel. Thus, it is most likely that acoustic duration differences would not be phonologically significant; instead, the duration of a consonant or a vowel may be a function of differences in quality, manner, or the structure of syllable or word. However, the duration differences of vowels in open vs. closed syllables may contribute to the impressionistic difference between tense and lax vowels. Note that F0 could also have an enhancement effect on the primary quality difference.

The measurement of the overall F0 is important in the analysis of vowel alternation since high vowels tend to have relatively higher F0 than lower ones (e.g. Peterson and Barney, 1952; House and Fairbanks, 1953; Lehiste and Peterson, 1961). With respect to vowel alternation in Javanese and Indonesian, if a vowel is lower, say, in a closed syllable than when it is in an open one, the F0 values may reflect this alternation: the vowel alternate in the closed syllable, if it undergoes lowering, may have a lower F0 value relative to its alternate in the open syllable. Parallel to the case for vowel duration, different F0s of the same vowel would have phonological significance in a tonal language like Mandarin Chinese, Thai, Kinyarwanda, etc. In a non-tonal language like Javanese and Indonesian, however, different F0s would most likely indicate a phonetic rather than a phonological effect.

The fourth measurement carried out in this chapter is vowel intensity. It has been argued that vowel intensity is lowest for high vowels and greatest for low ones (e.g. Ladefoged, 2001; Laver, 1994); thus, the high vowel [i] would have relatively lower amplitude as compared to the low vowel [a]. According to Ladefoged (2001), the amplitude difference between low vowels like [ɑ] and [ɔ], in which the mouth is more open, and high vowels like [i] and [u] is about 5 dB, if they are produced with equal degree of stress. A difference of ± 1 dB in intensity of synthetic vowels has been found to be noticeable (Flanagan, 1957), and a difference between 3 dB (Laver, 1994) to 5 dB (Ladefoged, 2001) is perceived as twice as loud. One should keep in mind, however, that there is a great deal of variation of intensity in the production of individual repetition, across tokens and speakers (e.g. House and Fairbanks, 1953). Therefore, comparing the amplitude of individual target segments across repetitions and across speakers may not be informative, as one repetition and/or speaker may be louder than the other during recording. In addition, the amplitude of a sound is not absolute; it is interpreted in relation to the amplitude of other sounds during speech (see, e.g., Laver, 1994 for other factors that may contribute to differences in the amplitude of sounds during speech).

Due to this complexity, to investigate relative amplitude of vowels, a segment in the frame sentence is designated to be the reference point of amplitude comparison for the target vowels. The reference point is the same for all tokens and for all speakers. For Javanese, the reference point is the first [ɔ] in [t^{ɦ}iwɔ̠čɔ]; for Indonesian, it is the first [a] in [diba̠ča]. Given the trend of amplitude for vowels with different heights, we would predict that a target vowel A is a lower vowel than a target vowel B, if the amplitude difference value between the target vowel A with the reference vowel is greater than the amplitude difference value between the target vowel B with the reference vowel. If this is the case, we would expect, for example, the amplitude difference between [i] and [a] in Indonesian to be greater than the amplitude difference between [e] and [a]. In comparing the heights of tense vs. lax vowels, assuming that tense vowels are higher than their lax counterparts, the amplitude difference between a tense vowel, for example [e], and [a] would be greater than the amplitude difference between the lax counterpart of [e], i.e. [ɛ], and [a].

The amplitude values in this study are obtained in several steps. First, the ESPS 'stats' computes the mean-square intensity, and then an awk script converts the root-mean-square values into a decibel scale. This is carried out by computing the square root of the mean-square intensity value calculated by the ESPS stats; after taking the common logarithm of the result, it is multiplied by 20.

With respect to the issue of whether vowel amplitude is a phonological or a phonetic issue, there has been no reported case where vowels, that are phonologically contrastive, acoustically express this contrast in the amplitude of the vowels; even though in a tonal or a stress system, it may go hand in hand with pitch (or F0) pattern (Laver, 1994). For Javanese and Indonesian vowels, one could assume that vowel amplitude is a phonetic effect.

Van Zanten (1989) and Adisasmito-Smith (1999b) find that Javanese vowel alternation is realized in the Indonesian of the bilingual Javanese/Indonesian speakers, supporting the impressionistic observation of Javanese influence on Indonesian. Given their findings, in the vowel alternation study here, I examine first the vowels in Javanese as the source of influence. The results of the acoustic measurements for vowel centralization cases are presented in § 3.3 and for vowel harmony cases in § 3.4. Then I analyze the Indonesian vowels as produced by the monolingual Indonesian speakers and compare the acoustic results of these Indonesian vowels with those as produced by the bilingual speakers of both Javanese dialects, with respect to vowel centralization in § 3.5, and with respect to vowel harmony in § 3.6. The values of the acoustic measurements with standard deviations for each speaker in the vowel alternation study are listed in Appendix C.

3.3 Acoustic measurements and analyses of word-final vowels in Javanese

In considering the acoustics of Javanese vowels, we are particularly interested in the realization of the impressionistic observations that Javanese vowels in root-final syllables alternate in being tense or lax depending on whether the syllable is open or closed. This tense/lax alternation is impressionistically observable. Consequently, the most prominent effect of this alternation would be vowel quality. The acoustic measurements of the F1/F2 values of root-final vowels in both dialects of Javanese are presented in § 3.3.1. The acoustic duration of these vowels are presented in § 3.3.2, the mean values of vowel F0 in § 3.4.3, and the mean values of vowel amplitude in § 3.3.4. I summarize the results briefly in § 3.3.5. In each case, I consider the results of the Central Javanese's productions, and then the results of the Eastern Javanese's.

3.3.1 Vowel formants

As discussed earlier, Javanese vowels are centralized in final closed (CVC) syllables and remain non-centralized in final open (CV) ones. The centralized high vowels in final CVCs, [ɪ] and [ʊ], are impressionistically judged by the speakers to be similar to the non-centralized mid vowels, [e] and [o]. The low vowel /a/ in final CV syllables is judged to be similar to the mid back vowel in closed syllables, [ɔ]. The plot of the F1/F2 peak values of these vowels would allow us to determine whether these impressionistic observations correlate with the actual production of these vowels. The analysis of vowel formants proceeds in the following order: (a) the same vowels are compared based on syllables structure, e.g. Ci# vs. CiC#; (b) vowels are compared based on their impressionistic similarity, e.g. CiC# vs. Ce#.

The F1/F2 measurements for Javanese vowels as produced by three Central Javanese male speakers are presented in Figure 3.4. Note that the F1/F2 values are pooled across these speakers. Each point in the F1/F2 plot (either a white square or a black circle), representing the mean value for F1 in the y-axis and the mean value for F2 in the x-axis, has a vertical and a horizontal error bars which cover two standard deviations. For all F1/F2 plots in this chapter, (□) represents open syllables and (●) closed syllables.

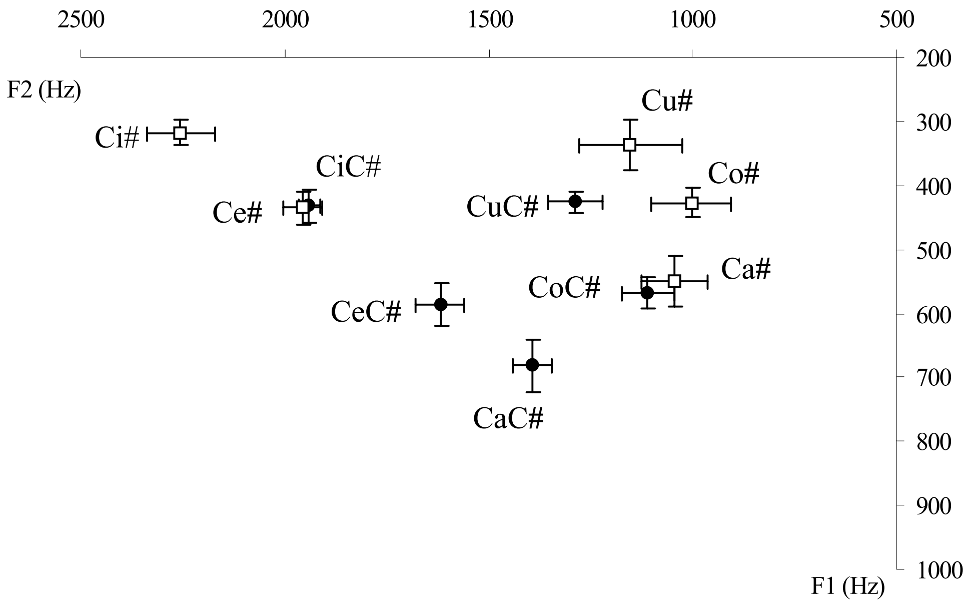


Figure 3.4: Mean F1/F2 values (in Hz) of Javanese final vowels in open vs. closed syllables for the Central Javanese speakers

I discuss first the comparison of the same vowels in open (CV) vs. closed (CVC) final syllables. The acoustic measurements of F1 and F2 of Javanese vowels show that for the CJ speakers, the high and mid vowels in CVC syllables are indeed more centralized and lower than their counterpart in CV syllables. For example, /i/ in final CVC syllable (CiC#) is more centralized than /i/ in the final CV syllable (Ci#). The back vowel /u/ in CuC# is lower but is only slightly centralized as compared to Cu#, since /u/ in Cu# is itself somewhat centralized. The F2 value difference in CV# vs. CVC# for /u/ is smaller as compared to the difference for the other non-low vowels. The low vowel /a/ in the final CVC syllable (CaC#) is lower and more centralized in the acoustic space than in the CV syllable (Ca#). Examined individually, the three speakers whose utterances are analyzed here show to be similar, with respect to the F1/F2 values for the final vowels.

The difference in F1/F2 values for each of these vowels in open vs. closed syllables (i.e. CiC# vs. Ci#, CuC# vs. Cu#, etc.) is statistically significant ($p < .05$). When the F1 and F2 values of these vowels are statistically analyzed separately, the results indicate that the F1 differences of vowels in CVC vs. CV syllables (e.g. F1 values of /i/ in CVC# vs. /i/ in CV#) are statistically significant for all vowels. The F2 differences of vowels in CVC vs. CV syllables are significant for all vowels but /u/. This suggests that even though the vowel in CuC# is more centralized than in Cu#, its magnitude is relatively less as compared to the magnitude for the other vowels in CV# vs. CVC# cases.

The pattern shown by the low vowel /a/ is unique. On the one hand, it exhibits the pattern of the non-low vowels in Javanese, i.e. Ca# is higher and more peripheral than CaC#. However, the actual realization of this difference is not what we would expect impressionistically. Given the pattern shown by the non-low vowels in Javanese, one would expect that /a/ in final CV syllables would be [a]-like, and in final CVC syllables would be less [a]-like. The acoustic measurements here, however, show the opposite. The actual acoustic realization of /a/ in final CV syllables confirms the impressionistic observation, in that it is similar to the acoustic realization of /o/ in final CVC syllables. This systematic pattern with respect to the influence of syllable structure on vowel alternation suggests the need to separate Javanese vowels into two phonological classes: non-low vowels vs. low vowel.

It is interesting to note that the back vowel /u/ in Cu# is relatively more central in the vowel space, as compared to the back vowel /o/ in Co#. There are several possible reasons. The first possible reason is speakers' variation. However, upon careful review of the F2 frequency, the values for Cu# are consistently higher than those for Co# for all three speakers. Another possible reason is the influence of the surrounding consonants. The final vowel /u/ in *susu* is preceded and followed by the fricative /s/; the one preceding it is /s/ in the onset of the final syllable, and the one following it is /s/ of the word *sekali* of the frame sentence. Being flanked by two alveolar fricatives may result in the raising of F2 value for /u/. This has been found to be the case in an electropalatographic and acoustic study of Catalan (Recasens, 1991).

Consider now the case where a vowel in a closed syllable is impressionistically similar to another vowel in an open syllable, e.g. CiC# vs. Ce#. As shown in Figure 3.4, the height of the high vowels /i, u/ in final CVCs is comparable to the height of the mid vowels /e, o/ in final CVs, respectively. The position of the vowel in CiC# and that in Ce# practically overlap in the acoustic space. For the back vowels, the vowel in CuC# is more centralized than that in Co#. The differences of these vowels are not statistically significant for CiC# vs. Ce#. For the pair CuC# vs. Co#, the differences are statistically significant, even though these come primarily from the differences in F2 values (i.e. centralization) and not in F1 values (i.e. height).

The low vowel /a/ in open syllables is slightly higher and more peripheral as compared to the mid vowel /o/ in closed syllables. The differences between these two vowels are not statistically significant.

These acoustic results strongly support the observations that for the Central Javanese speakers, non-low vowels centralize and are lower in final CVC syllables compared to in final CV ones. In addition, these results show that the impressionistic observations of the similarity between the vowels in the following pairs: CiC# vs. Ce# and Ca# vs. CoC# corresponds with their acoustic manifestations (especially in terms of height). The case with CiC# vs. Ce# explains the orthographic representation of the vowels shown earlier in § 3.1, data set in (2). For the pair CuC# vs. Co#, despite their impressionistic similarity, the vowel in CuC# is more centralized than that in Co#. This suggests that the source of their similarity is influenced primarily by their similar height and secondarily by their degree of backness. A perceptual study would be needed to determine whether native speakers can differentiate the vowels in CiC# vs. Ce# and in CuC# vs. Co#, and whether other acoustic aspects like duration, F0 and/or amplitude provide additional cues for the impressionistic similarity of these vowels.

I turn now to the pattern of the Javanese vowels in the Eastern Javanese dialect. Based on impressionistic observations, vowel alternations in final syllables are similar for the Central and the Eastern dialects of Javanese, i.e. all non low vowels centralize in final CVC syllables and remain peripheral in final CV syllables, and the realization of the low vowel /a/ in final CV syllables is similar to that of the mid vowel /o/ in final CVC syllables. The F1/F2 plot of these vowels is shown in Figure 3.5.

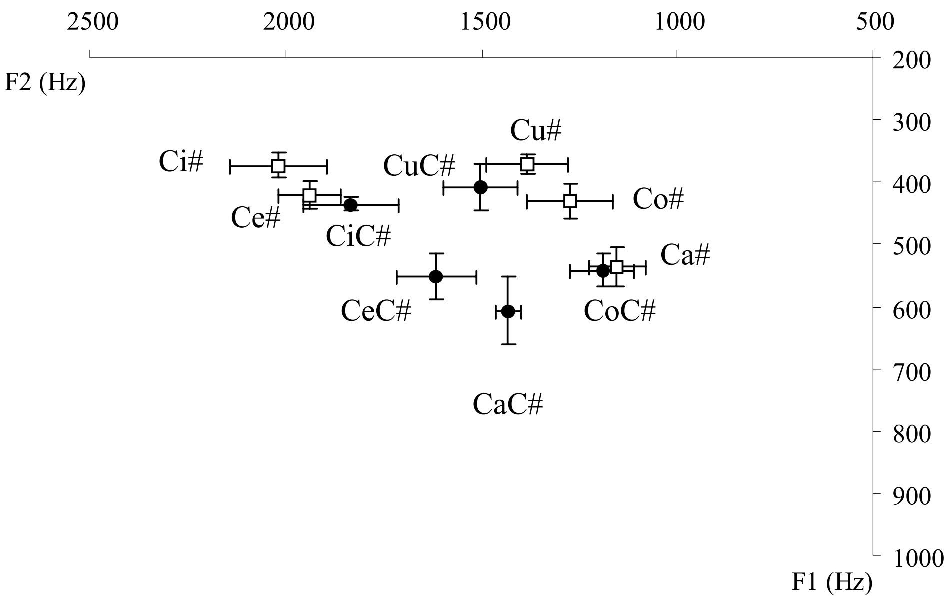


Figure 3.5: Mean F1/F2 values (in Hz) of Javanese final vowels in open vs. closed syllables for the Eastern Javanese speakers

Comparing the production of Javanese vowels by the Eastern Javanese speakers to that by the Central Javanese speakers (shown in Figure 3.4), it is striking that all of the vowels by the Eastern Javanese speakers are more centralized. This may be due to the differences among these particular speakers.

As shown in Figure 3.5, the high vowels in closed final syllables (CiC# and CuC#) are lower and more centralized than in open final syllables (Ci# and Cu#) in the acoustic space. The front mid vowel in CeC# is lower and more centralized than in Ce#. The back vowel in CoC# is lower but more peripheral than in Co#, with a difference in F2 values of 81 Hz. The low vowel /a/ in Ca# is higher and more peripheral than in CaC#. The F1/F2 differences of each vowel in open vs. closed final syllables are statistically significant. The statistic results also show that the F1 differences are statistically significant for each vowel in open vs. closed syllables, but the F2 differences are statistically significant for these vowels, except /o/. These results show that for the Eastern Javanese speakers, non-low vowels centralize (except for /o/) and are lower in final CVC syllables.

As with the case for the Central Javanese speakers, the relative position of the high vowel in Cu# in the acoustic space is more centralized than the mid vowel in Co#, suggesting that this phenomenon in Javanese is probably not due to variation among these speakers; rather it may result from the structure of the word or it may be due to language specific factor. The vowel /u/ in English (Bradlow, 1993) and in Buginese (Podesva and Adisasmito-Smith, 1999) also show to be relatively more centralized than /o/ in the respective language, which may suggest that it is not uncommon for /u/ to be more centralized in the acoustic space, as compared to /o/.

The case with the vowels in Eastern Javanese that are impressionistically similar, CiC# vs. Ce#, CuC# vs. Co#, and Ca# vs.

CoC#, is not unlike the case in Central Javanese. For each pair, the vowels have similar height in the acoustic space, which corresponds to their F1 values. The vowels in CiC# and CuC# are relatively more centralized than those in Ce# and Co#, respectively. The vowels in CoC# and Ca# practically overlap in the acoustic space. Statistical analyses indicate that the differences in the acoustic space for the vowels in each pair are the following: (a) the difference between /i/ in CiC# and /e/ in Ce# are borderline ($p = .05$), primarily due to F1 differences (i.e. height); (b) the difference between /u/ in CuC# and /o/ in Co# are significant mainly due to the difference in F2 values (i.e. backness); (c) the difference between /o/ in CoC# and /a/ in Ca# are not significant.

To summarize the results here, non-low vowels in the Eastern and Central dialects of Javanese lower in root-final closed syllables, and the low vowel /a/ in root-final open syllables is higher and more peripheral than in closed syllables. With respect to vowels that are impressionistically similar, in the Central dialect, there is a high degree of overlap between CiC# and Ce#; in the Eastern dialect, the vowels in CiC# and in Ce# are of similar height but the former is more centralized than the latter. In the case of the back vowels, for both dialects, the vowels in CuC# and Co# are of similar height, but CuC# is more centralized than Co#. For the pair of Ca# vs. CoC#, they practically overlap in the acoustic space for the speakers in both Javanese dialects. These results indicate that, as far as vowel quality is concerned, they support the impressionistic observations: i.e. (1) vowel quality changes when the vowels are in open vs. closed final syllables, and (2) high vowels in closed final syllables are similar to mid vowels in open final syllables and low vowel in open final syllables is similar to mid back vowel in closed final syllables. For the vowels that are impressionistically similar, CiC# vs. Ce# and CoC# vs. Ca#, the contribution of height seems to be very important. In the next section, I turn to the duration measurements of vowels in open and closed syllables.

3.3.2 Vowel durations

In this section, vowels are analyzed in the following order: (a) same vowel in open vs. closed syllables; (b) different vowels in the same syllable type, e.g. Ci# vs. Ce#, CiC# vs. CeC#; (c) vowels that are impressionistically similar. We start first with the Central Javanese case.

As discussed earlier, vowel length is not a contrastive feature in Javanese. Thus, here, we expect to see that duration differences would be a function of syllable structure and/or intrinsic vowel quality. These differences, however, may enhance the similarity or dissimilarity or particular vowels (e.g. similarity of CiC# vs. Ce#, and dissimilarity of Ci# vs. CiC#). Following the tendency found in many languages (Maddieson, 1985), we would expect to see that Javanese vowels in open syllables are greater in duration than those in closed syllables. This is indeed the case for the Central Javanese speakers, as shown in Figure 3.6, for all of the vowels. In this chart, each bar represents the mean duration value, pooled across three speakers. White bars represent vowels in open syllables and gray bars represent vowels in closed syllables. The error bars in the charts cover two standard deviations.

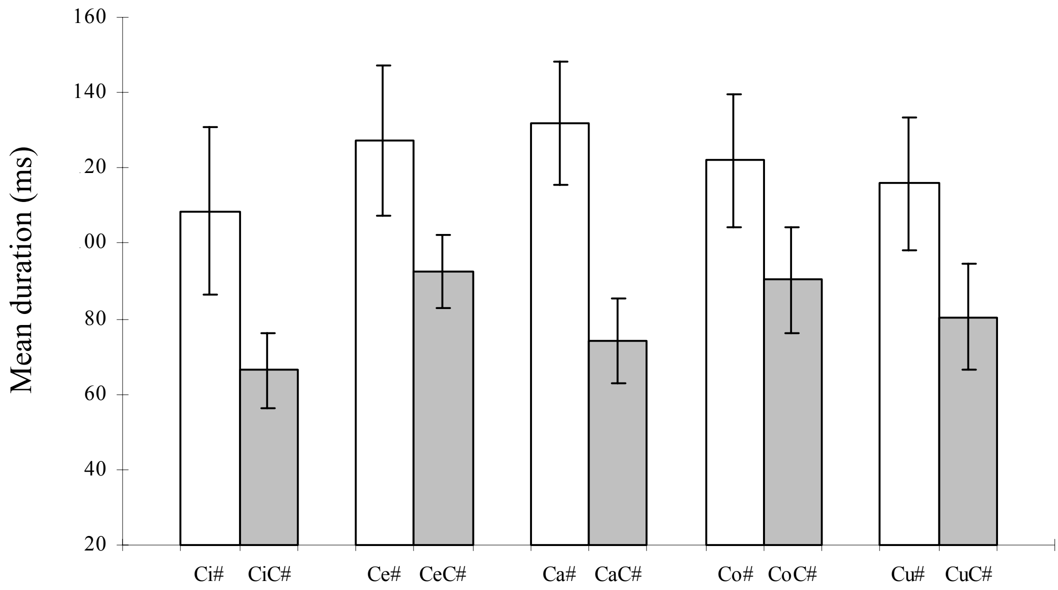


Figure 3.6: Mean durations (in ms) of Javanese final vowels in open vs. closed syllables for the Central Javanese speakers

As expected, lower vowels are longer in duration relative to higher ones (e.g. Maddieson, 1985), at least in final open syllables. The one surprising result is that in final closed syllables, the duration of the low vowel /a/ is less than that of the mid vowels. The duration differences between vowels in closed vs. open final syllables range from 31.5 ms for /o/ to 57.9 ms for /a/, with the range of ratios of 1:1.4 to 1:1.8, respectively. These differences are statistically significant for all vowels.

The mean durations of vowels in the same syllable type, e.g. Ci# vs. Ce#, etc., and CiC# vs. CeC#, etc., show that their relative differences correspond to the underlying height of the vowels. High vowels tend to be smaller in duration than lower vowels. The only exception is the duration of vowel in CaC# being smaller than the duration of vowels in CeC# and CoC#. The ranges of difference are between 5 ms (for Ce# vs.

Ca#) and 18 ms (for Ci# vs. Ce#) in the CV cases, and between 10 ms for (CuC# vs. CoC#) and 16 ms (for CiC# vs. CeC#) in the CVC cases. For the CV cases, the differences are statistically significant for /i/ vs. /a/, /a/ vs. /u/, and marginally significant for /i/ vs. /e/ (P = .04); in the CVC cases, the differences are statistically significant for /i/ vs. /e, o, u/, /e/ vs. /a, u/, /o/ vs. /a, u/.

Comparing the vowels that are impressionistically similar, the mean duration of the vowels in CiC# is shorter than in Ce# by 61 ms, and the mean duration of the vowels in CuC# is shorter than in Co# by 41 ms. The mean duration of /o/ in CoC# is shorter than /a/ in Ca# by 42 ms. The duration differences are statistically significant for all three pairs of cases.

The results of the duration measurements here suggest that while the underlying height may contribute to the duration difference (especially for vowels in the same syllable type), the fact that these vowels are in a CV vs. CVC syllable plays a bigger role in determining their relative duration. The magnitude of differences here is much greater compared to that for vowels with different height in the same syllable type.

I turn now to vowel durations for the Eastern Javanese speakers. As shown in Figure 3.7, the duration of vowels in closed vs. open syllables follows the trend across languages, in that it is shorter for vowels in closed syllables than in open ones. The differences in duration for these vowels range from 20 ms for /o/ to 64 ms for /a/, with the range of C<u>**V**</u>C:C<u>**V**</u> ratios of 1:1.3 to 1:2.3, respectively. These differences are statistically significant.

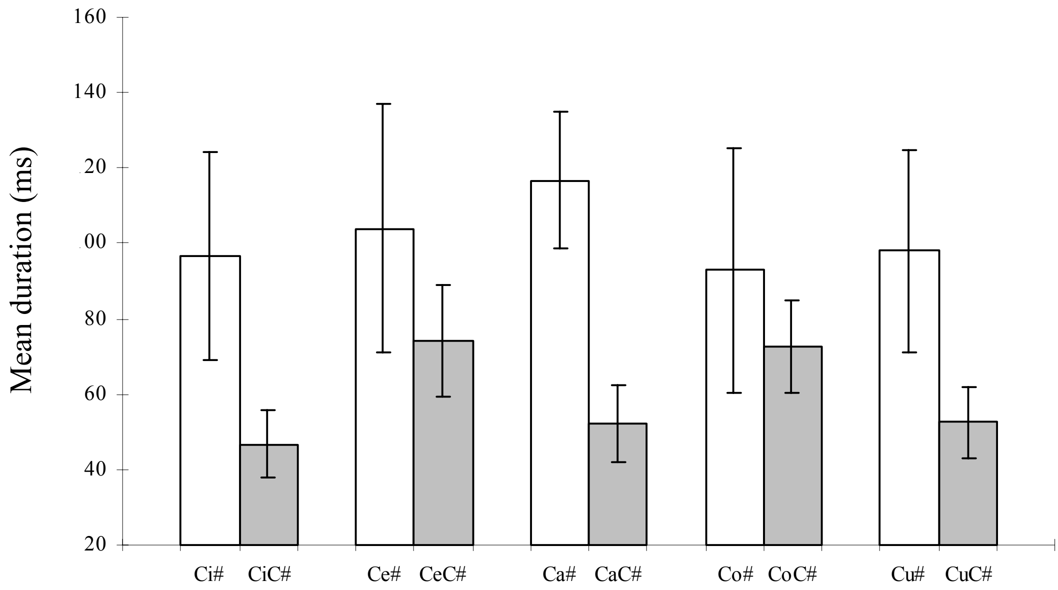


Figure 3.7: Mean durations (in ms) of Javanese final vowels in open vs. closed syllables for the Eastern Javanese speakers

The mean duration of vowels in the same syllable type, such as Ci# vs. Ce#, CiC# vs. CeC# etc., show the commonly found tendency where the high vowels tend to be shorter than the low vowels, though not without exception. The mean duration of /o/ in final CV syllables is similar to that of /u/ (5 ms difference). Statistically, the mean duration differences of vowels in the final CV syllables are marginally significant for /i/ vs. /a/, and for /a/ vs. /o, u/. The mean duration of CaC# is shorter than the mean duration of CeC# and CoC#, and is identical to that of CuC#. The greatest duration difference is 24 ms (Ca# vs. Co#) for the CV cases, and 27 ms (CiC# vs. CeC#) for the CVC cases. For the final CVC cases, the mean duration differences are statistically significant for /i/ vs. /e, o/, /e/ vs. /a, u/, /a/ vs. /o/, and /o/ vs. /u/.

For the vowels that are impressionistically similar, the mean duration of the vowel in CiC# is shorter by 57 ms as compared to that in Ce#, by 70 ms for the vowels in CuC# vs. Co#, and the vowel in CoC# is shorter by 44 ms the vowel in Ca#. In brief, the vowels in the closed syllable are shorter than those in the open syllable. The differences are statistically significant.

Comparing the effect of vowel height vs. syllable structure on vowel duration for the Eastern Javanese speakers, the results here suggest that syllable structure plays a major role in determining the duration difference of Javanese vowels. Vowel height may also play a role, even though it seems to be to a much lesser extent. This observation is based primarily on the fact that the duration difference is much greater when syllable structure is taken into account, as compared to vowel height. Yet these duration differences do not negate the effect of the similarity of vowel quality between CiC# vs. Ce# and between CoC# vs. Ca#.

Comparing the ranges of vowel durations in Javanese for the Eastern Javanese vs. the Central Javanese speakers, it is interesting to note that the ranges for the Eastern Javanese speakers tend to be lower (93-117 ms for the final CV cases and 47-74 ms for the final CVC cases), as compared to the ranges for the Central Javanese speakers (109-132 ms for the final CV cases and 66-92 ms for the final CVC cases). This difference in duration ranges may result from the difference in speech rate. Speech rate has been found as a factor affecting the duration of consonants and vowels in that their duration tends to be shorter when produced in a fast rate than in a normal or slow rate (e.g. Gay, 1978; Port, 1981; Crystal and House, 1988; Kessinger and Blumstein, 1998; Allen and Miller, 1999, to name a few). If this is the case for the findings for the Javanese vowels in the present study, the recorded Eastern Javanese speakers, whose utterances are analyzed here, may have read the Javanese wordlist at a relatively greater speech rate, as compared to the Central Javanese speakers.

In the next section, I turn to the analysis of the fundamental frequency of vowels.

3.3.3 Vowel fundamental frequency

Previous studies (e.g. Peterson and Barney, 1952; House and Fairbanks, 1953; Lehiste and Peterson, 1961; Ohala and Eukel, 1987) have shown that high vowels tend to have higher F0 and low vowels tend to have lower F0. There are two possible sources from which this phenomenon originates, as stated by ‘t Hart et al. (1990): "… the mechanical link between tongue-body elevation and the vertical displacement of the larynx…", and "… the influence of the varying degrees of constriction in the vocal tract on the airflow and on the size of the transglottal pressure drop." With respect to Javanese vowels, especially those that are impressionistically similar, (i.e. CiC# vs. Ce#; CuC# vs. Co#, and Ca# vs. CoC#), one would then expect to find that vowels with similar F1/F2 values have similar F0. It is also possible, however, that we would find the F0 of these vowels to correspond with their underlying height.

The order of analysis in this section is the following: (a) different vowels in the same syllable type, (b) same vowel in open vs. closed syllables, and (c) vowels that are impressionistically similar. The mean overall F0 values for Javanese vowels in final syllables for the Central Javanese speakers are shown in Figure 3.8.

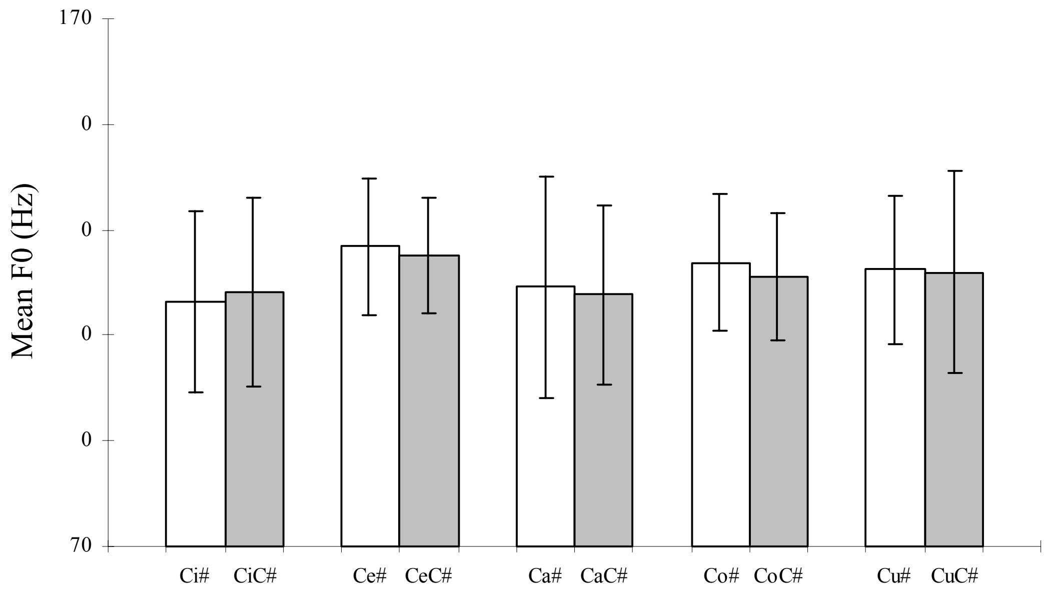


Figure 3.8: Mean overall F0 values (in Hz) of Javanese final vowels in open vs. closed syllables for the Central Javanese speakers

In the final open syllables (white bars), the mean F0 values for the high vowels /i/ and /u/ are lower than for the mid vowels, contrary to the expected pattern; these differences are 11 Hz for the front vowels and 2 Hz for the back vowels. The mean F0 value for the low vowel /a/ (acoustically realized as [ɔ]) is lower relative to the mean F0 values for the mid vowels, by 8 Hz as compared to /e/ and by 5 Hz as compared to /o/. The results for vowels in final closed syllables (gray bars) mirror those in final open syllables. The differences for the front vowels are 7 Hz, and for the back vowels 1 Hz. The mean F0 value for /a/ is lower than that for /e/ (by 7 Hz) and for /o/ (by 3 Hz). None of these differences, both in the open and in the closed syllable cases, reaches statistical significance.

The F0 values for the individual speakers (see Appendix E) were further examined to see if the values for any speaker show a different pattern. For the vowels in final open syllables, the mean value differences for different vowels in Figure 3.8 are consistent with the mean value differences for these vowels by the individual speakers. For the vowels in final closed syllables, the mean F0 values for different vowels in Figure 3.8 reflect the mean values for these vowels for two speakers. One speaker (CJ_m3) shows mean values that follow the expected pattern for the high vs. mid vowels, even though the differences are quite small (2-3 Hz); the mean value for the low vowel is 3 Hz lower than that for the mid vowels. Thus, in general, the pitch pattern of Javanese vowels for these Central Javanese speakers does not follow the expected trend of vowel intrinsic pitch. This may indicate that at least for some speakers (of Javanese and perhaps of some other languages), the pitch pattern of vowels does not necessarily go hand in hand with the differences in vowel quality. However, the structure of the word list may also play a role in determining the results above. It is important to remember that even where these differences have been observed, the magnitude of the differences is small.

Comparing vowels in open vs. closed syllables (i.e. between tense and lax vowels), their F0 values are greater in open syllables (i.e. tense) than in closed ones (i.e. lax), except for /i/. The F0 differences are very small, ranging from almost 1 Hz for Cu# vs. CuC# to 3 Hz for Co# vs. CoC#, and are statistically not significant. We have seen earlier that in the acoustic space, high and mid tense vowels are higher than their lax counterparts, and the low vowel in Ca# (realized as [ɔ]) is higher than its counterpart in CaC#. Thus, except for /i/, vowels in open syllables tend to have higher F0 than those in closed syllables. Given the fact that the differences are very small, these results need to be considered as tentative. Note that it has been argued that the just-noticeable difference (JND) in pitch discrimination is about 1 Hz in the span of fundamental frequency from 80-160 Hz (e.g. Flanagan, 1957; Lehiste, 1970). Some other perceptual studies based on synthetic stimuli even claim that the JND for pitch can be as low as 0.3 - 0.5 Hz (e.g. Flanagan and Saslow, 1958). Thus, in the Javanese of the speakers from Central Java, the F0 differences of a vowel phonetically realized as its high vs. low alternates are within the JND of pitch discrimination.

For the pairs of vowels that are impressionistically similar, the mean F0 values for /i/ in CiC# and for /u/ in CuC# are lower than those for /e/ in Ce# and for /o/ in Co#, respectively. The mean differences are 9 Hz for the front vowels and 2 Hz for the back vowels. For the low vowel, the mean value for /a/ in Ca# is 2 Hz lower than that for /o/ in CoC#. As briefly mentioned earlier, one might expect vowels with similar F1/F2 values to have similar F0 values. If the difference of 2 Hz for CuC# vs. Co# and for Ca# vs. CoC# is too small to be of significance, then we might say that back vowels with similar F1/F2 values have similar F0, but that this is not the case for the front vowels. With respect to the possibility that F0 values reflect the underlying height of the vowels, this is not borne out either, since the underlying high vowels in the CVC syllables show to have lower F0 than the underlying mid vowels in the

CV syllables. These results seem to suggest that, for Javanese vowels that are impressionistically similar, the underlying height of the vowel pairs and/or their similarity in formant structure do not correlate, at least not in a straightforward way, with their F0.

To summarize, the case of vowels in open vs. closed final syllables, whereby the vowels in the open syllables are higher in the acoustic space than the same vowels in the closed syllables, may suggest the correlation between vowel F0 and vowel height in Javanese. However, the small mean value differences may also indicate the tentativeness of these results. In addition, the results also show that they are not always consistent with the expected pattern.

Next, I analyze the F0 measurements of Javanese vowels for the Eastern Javanese speakers. The results are presented in Figure 3.9. I also compare the results for these speakers with those for the Central Javanese speakers.

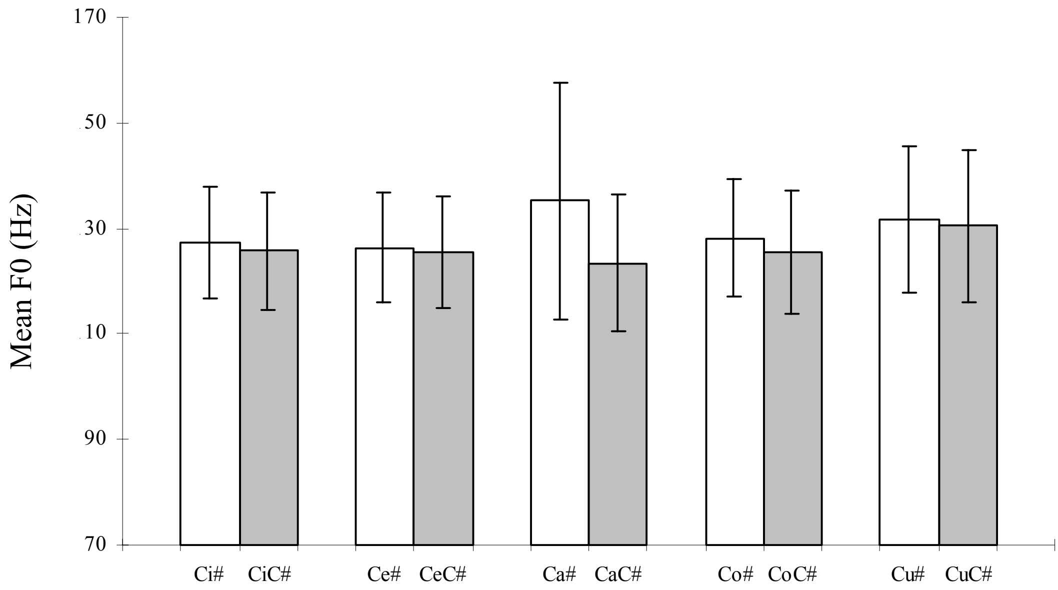


Figure 3.9: Mean overall F0 values (in Hz) of Javanese final vowels in open vs. closed syllables for the Eastern Javanese speakers

In open final syllables, the mean F0 values of the high vowels are slightly higher than those of mid vowels; the mean F0 of /i/ in Ci# is 1 Hz higher than that of /e/ in Ce#, and the mean of /u/ in Cu# is 4 Hz higher than that of /o/ in Co#. The mean F0 of /a/ is higher than non-low vowels, contrary to the expected pattern. Looking at the F0 values for the individual speakers, one speaker (EJ_m1) has particularly high F0 values for the final vowel in *rata*, in the range of 153-166 Hz. The F0 values of the other vowels for this speaker are within the same range as for the other two speakers. This explains why the mean F0 value of vowels in Ca# is unexpectedly high. When the F0 values for the speaker EJ_m1 are excluded, the mean F0 value for /a/ in Ca# is 123 Hz. This mean value is the lowest as compared to the mean values for the other higher vowels. In closed final syllables, the F0 mean values for the front vowels are identical; for the back vowels, the mean value for /u/ is higher by 4 Hz as compared to that for /o/. The mean value for the low vowel, including the values for speaker EJ_m1, is 124 Hz; excluding this speaker, the mean value is 118 Hz. In either case, the mean value for /a/ is the lowest relative to the non-low vowels. The F0 differences of these different vowels, in open and in closed syllables, including and excluding speaker EJ_m1, are not statistically significant.

Comparing the mean F0 values of the vowels in open vs. closed final syllables, they are greater in open than in closed ones. The differences are small, ranging from 1-3 Hz for the non-low vowels. As mentioned earlier, the F0 values of /a/ for speaker EJ_m1 are higher relative to the values for the other vowels. When the F0 values for this speaker are excluded from the Ca# vs. CaC# contrast, the mean value difference for /a/ in the two different syllable types are 5 Hz, with /a/ in Ca# with the higher mean F0. The F0 differences for vowels in open vs. closed final syllables are not statistically significant (whether or not the values for speaker EJ_m1 are included). We have seen earlier that vowels in closed final syllables are lower in the acoustic space as compared to their counterpart in open final syllables (see Figure 3.5). One may conclude, then, that the high alternate of Javanese vowels (in the open syllable) tends to have greater F0 as compared to their low counterpart (in the closed syllable).

Comparing the vowels that are impressionistically similar, the mean values for /i/ CiC# and /e/ in Ce# are identical; the mean value for /u/ in CuC# is 2 Hz higher than for /o/ in Co#; and the mean value for /o/ in CoC# is 9 Hz lower than for /a/ in Ca# when speaker EJ_m1 is included, but 3 Hz higher when this speaker is excluded. Statistical analysis indicates that the differences in F0 mean values are not significant for any of the vowel pairs. This result seems to indicate that there may be a weak correlation between F0 and underlying height of vowels.

To summarize, the results for the Eastern Javanese speakers suggest that the F0 mean values of vowels reflect the expected tendency whereby higher vowels have higher F0 as compared to other lower vowels. In contrast, we see earlier that the results of the F0 measurements for the Central Javanese speakers are not always consistent with the expected tendency.

3.3.4 Vowel amplitude

As discussed previously, high vowels tend to have lower intensity as compared to lower vowels (Laver, 1994; Ladefoged, 2001; among others). The difference between vowels such as [i] and [u] vs. [a] and [ɔ] could be as much as 5 dB, a difference which is equivalent to doubled loudness (Ladefoged, 2001). I have also discussed the fact that the amplitude of a (speech) sound is not absolute, but that it is relative to the amplitude of the surrounding sounds. Consequently, the method used to measure vowel amplitude here is the comparison of the amplitude values of two vowels. For Javanese, the vowel determined as the anchor point of comparison is the low vowel /a/ in the penultimate syllable of the word /diwača/ in the frame sentence. Note that this vowel is acoustically realized as [ɔ]. The target vowel is either the penultimate or the final vowel of the target word. In the following example, the anchor vowel /a/

and the target penultimate vowel /i/ are underlined, and the target word is in bold face: /diwa̲ča **si̲si** səpisan/.

If high vowels tend to have lower amplitude than lower vowels, what we would predict to see here is that the difference in amplitude values between [a] and [i] would be greater than the difference between [a] and [e], for example. In cases of vowels that are impressionistically similar, if the acoustic lowering of, say, /i/ in CiC# has some bearing on vowel amplitude, we predict that the amplitude difference between the penultimate [ɔ] in /diwa̲ča/ and [i] in Ci# would be greater than the difference between this penultimate [ɔ] and [ɪ] in CiC#. Further, considering the high degree of overlap between the lowered /i/ and the tense /e/, we might also see that the amplitude difference between /a/ and /i/ in CiC# (i.e. lowered /i/) is similar to the difference between /a/ and /e/ in Ce#.

Note that the bars in the graph presented in this section represent the **mean value of amplitude difference** between /a/ and the target vowel, rather than the mean value for the target vowel itself. To interpret the result, when a bar A has a **greater** value than a bar B, the amplitude of A is **lower** than the amplitude of B. In other words, amplitude difference goes the opposite direction of relative amplitude. Thus, if vowel amplitude shows a correlation with vowel height, we would expect to see the amplitude difference between /a/ and /i/ in an open final syllable (represented as the bar **Ci#**) to be **greater** than the difference between /a/ and /e/ in an open final syllable (represented as the bar **Ce#**). The value of the amplitude difference for /a/ as a target vowel would be zero dB or close to zero dB. When the amplitude difference is smaller than zero, it indicates that the amplitude of /a/ is lower than that of the target vowel. The predicted correlation of vowel amplitude is shown in (7).

(7)	a.	comparison of individual vowel amplitude (referred to as **relative amplitude**)	i, u < e, o < a i, u < ɪ, ʊ e, o < ɛ, ɔ ɔ < a
	b.	comparison of vowel amplitude represented as bars in graph (referred to as **amplitude difference**)	i, u > e, o > a i, u > ɪ, ʊ e, o > ɛ, ɔ ɔ > a

The results of the amplitude comparison of /a/ and the Javanese vowels in final syllables for the Central Javanese speakers are presented in Figure 3.10. The order of analysis in this section is the following: (a) vowels in the same syllable type are compared to each other, (b) the same vowel in different syllable types is compared, and (c) pairs of vowels that are perceived as similar are compared.

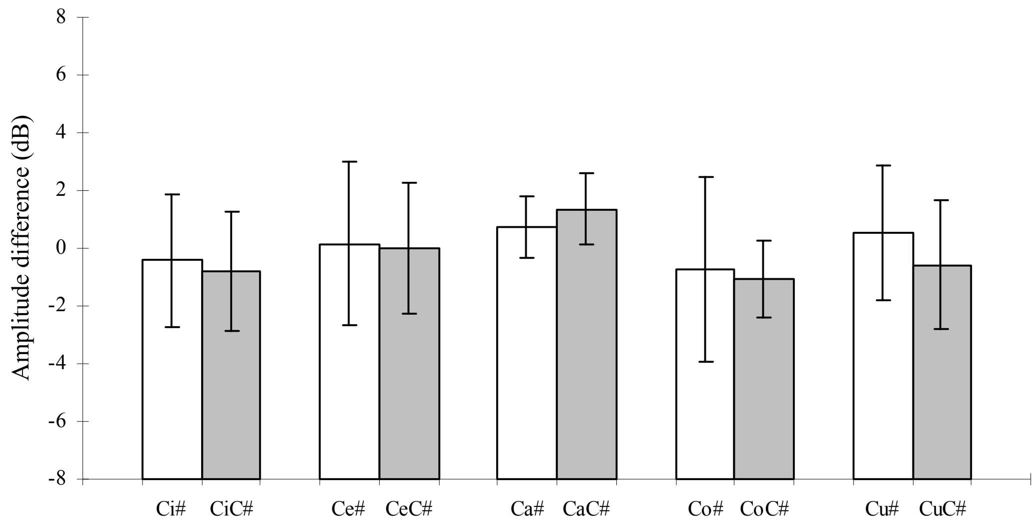


Figure 3.10: Differences of the mean amplitude (in dB) of Javanese /a/ of the frame sentence vs. the mean amplitude of final vowels in open and closed syllables for the Central Javanese speakers

In the open syllable case, the mean value of the amplitude difference for /a/ is greater than for the other higher vowels, contrary to the prediction. For the front vowels, the mean difference for /e/ is greater than for /i/, opposite to the expected direction. For the back vowels, the mean difference for /o/ is smaller than for /u/. The mean values of amplitude difference for the vowels in closed syllables are similar to those for the vowels in the open syllable case, in that they are the greatest for /a/, greater for /e/ than for /i/, and smaller for /o/ than for /u/. These results suggest that, in the Javanese of the Central dialect speakers, vowel relative amplitude does not exhibit the expected trend.

Comparing a vowel in an open vs. a closed final syllable, the mean values of the amplitude difference for vowels in the open syllables are slightly greater than in the closed syllables, for the non-low vowels. For the low vowel/a/, the opposite is the case, in that the mean values are greater in the closed syllables (realized as [a]) than in the open syllables (realized as [ɔ]). Statistically, these differences are not significant. This result may suggest that non lowered (or tense) high and mid vowels tend to have lower relative amplitude than their lowered (or lax counterpart), even though it seems that the difference is quite small; in addition, the relative amplitude of the low vowel realized as [a] (i.e. CaC#) is lower than of this vowel realized [ɔ] (i.e. Ca#).

For vowels that are impressionistically similar, the mean value of the amplitude difference for the front vowel in Ce# is greater than for the vowel in CiC#. The difference mean values are similar for the back vowels in Co# and in CuC#. The difference mean value is greater for the vowel in Ca# than for the vowel in CoC#. The result here suggests no systematic correlation between impressionistically similar vowels and their relative amplitude.

Next, I turn to the amplitude comparison of /a/ and the Javanese vowels in final syllables for the Eastern Javanese speakers. The results are presented in Figure 3.11.

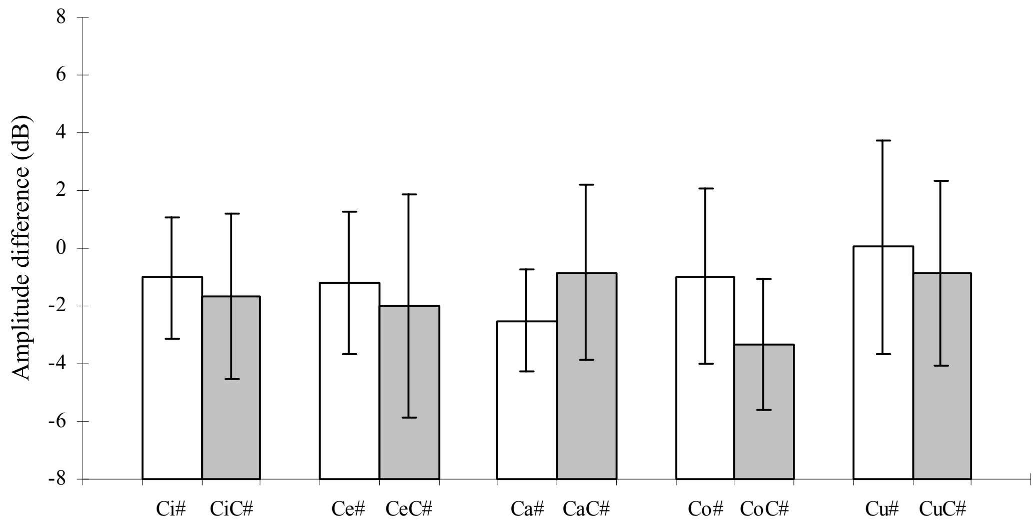


Figure 3.11: Differences of the mean amplitude (in dB) of Javanese /a/ of the frame sentence vs. the mean amplitude of final vowels in open and closed syllables for the Eastern Javanese speakers

For these speakers, the mean values of amplitude difference for the high vowels in the open final syllables tend to be greater than for the lower vowels, as predicted. In the closed final syllables, the mean values for the high vowels are greater than for the mid vowels. However, the mean value for /a/ is greater than it is for the mid vowels in the CVC case. As shown here, the vowels in Ca# and in CoC# have the lowest amplitude difference mean values, as compared to the other vowels in the same syllable type. This suggests that /a/ in Ca#, phonetically realized as [ɔ], has the greatest relative amplitude.

Also shown here, the amplitude difference mean value for a non-low vowel in the final open syllables (i.e. tense) is greater than for the same vowel in the closed syllables (i.e. their lowered counterpart). This result suggests that, excluding /a/, a tense vowel tends to have lower relative amplitude than its lax counterpart. If, as stated by Ladefoged (2001), the degree of mouth opening correlates with the relative amplitude of the vowels, one may argue that, in the Javanese of the Eastern dialect speakers, lax vowels are produced with a greater degree of mouth opening as compared to tense vowels.

For the pairs of vowels that are impressionistically similar, the amplitude difference mean value for Ce# is slightly greater than for CiC#, it is similar for Co# and CuC#, and greater for Ca# than for CoC#. Statistically, these mean value differences are not significant. The result here shows no systematic correlation between impressionistically similar vowels and their relative amplitude.

To summarize briefly, Javanese vowels as produced by the Eastern Javanese speakers show that lower vowels tend to have greater relative amplitude when compared to higher vowels, with the exception of [a], and lax vowels tend to have greater relative amplitude than their tense counterpart. The difference in the results between the two speaker groups may indicate that speaker variation, whether as an individual or as a group, affects the acoustic results of relative amplitude for vowels. Note that these differences correlate with the F0 differences which go in the expected direction for the Eastern Javanese speakers, but not for the Central Javanese speakers. The results for vowel amplitude in Javanese, especially the Central dialect, are quite unusual. Further studies with greater number of speakers would be needed to determine vowel amplitude pattern in this dialect.

3.3.5 Summary of results

In Table 3.4, I summarize the results of the acoustic measurements of Javanese final vowels, as produced by the speakers from Central and Eastern Java. Bold prints indicate differences among the speaker groups.

Table 3.4: Summary of the acoustic measurements of Javanese vowels in the final syllables

	Central Javanese	Eastern Javanese
Formant structure	1. Except for /a/, vowels lower in final CVCs **2. Vowel height: CiC# ≈ Ce# CuC# ≈ Co#**	1. Except for /a/, vowels lower in final CVCs **2. Vowel height: CiC# ≈ Ce# CuC# ≈ Co#**
Vowel duration	1. Vowels in final CVs are longer than those in final CVCs 2. High vowels tend to be shorter than lower vowels	1. Vowels in final CVs are longer than those in final CVCs 2. High vowels tend to be shorter than lower vowels
Fundament-al frequency	**F0 does not always correlate with vowel height**	**F0 pattern may correlate with vowel height**
Amplitude difference	**1. Vowel height: no consistent pattern** 2. Non-lowered vowels tend to have lower relative amplitude than lowered vowels 3. Impressionistically similar vowels do not always have similar relative amplitude	**1. Vowel height: except for /a/, lower vowels tend to have lower relative amplitude than higher vowels** 2. Non-lowered vowels tend to have lower relative amplitude than lowered vowels 3. Impressionistically similar vowels do not always have similar relative amplitude

We have seen that based on the acoustic investigation carried out here, the most systematic difference of vowel alternation in Javanese in final syllables are realized in their formant structure. The acoustic similarity in the mean F1/F2 values for [ɪ] in CiC# vs. [e] in Ce# and for [ɔ] in Ca# vs. in CoC# supports the impressionistic similarity. The similarity in height between [ʊ] in CuC# and [o] in Co# seems to be sufficient for their impressionistic similarity, despite the fact that [ʊ] is more centralized than [o]. This may be the result of parallel perception between front and back vowels, in that if the front vowels lower in closed syllables, then the back vowels would also lower. Perhaps a compounding factor for the perceived similarity between [ʊ] and [o] is related to the difference in acoustic vowel space distribution in languages with different vowel systems. In a six-vowel system (including schwa) like Javanese, it is possible that a vowel, say /u/, with a certain range of F1 values (i.e. height) would be perceived as [u], and that when the F1 value reaches outside of that range, it would be perceived as the next lower vowel, i.e. [o]. See Disner's (1983) and Bradlow's (1993) acoustic studies on vowel quality across languages, and Bradlow's (1993) perceptual studies of vowels in English and Spanish.

With respect to the other acoustic characteristics of vowels that we have seen in this section, the duration pattern of vowels, whether they are acoustically similar or different, is primarily determined by the shape of the syllable. The results on fundamental frequency indicate that vowel quality in Javanese shows no consistent pattern with respect to vowel height. Comparisons of the difference between the relative amplitude of the anchor vowel /a/ and that of target vowels show that mid vowels tend to have greater amplitude than high vowels; this is consistent for one speaker group. The results indicate that vowels with impressionistic similarity do not have similar amplitude. These results warrant a perceptual study to determine whether Javanese speakers distinguish the vowels in the following pairs: CiC# vs. Ce#, CuC# vs. Co#, and Ca# vs. CoC#, and what (combination of) cues being used by the listeners in their decision.

In the next section, I analyze and discuss the acoustic measurements of Javanese vowels in the penultimate syllables. This is to determine whether these vowels undergo vowel harmony.

3.4 Acoustic measurements and analyses of penultimate vowels in Javanese

As we have seen in the previous section, the acoustic difference in the realization of the final vowels in Javanese is determined by syllable structure. The penultimate vowels in Javanese are claimed to harmonize with the final ones if they share the same vowel quality, as described earlier. Impressionistically, all vowels undergo harmony in the Eastern dialect, but only the mid and low vowels do in the Central dialect. If vowel harmony is a phonological process, one would predict that, in a $CV_1CV_2(C)$ word where $V_1=V_2$, the penultimate and the final vowels share similar values in their acoustic measurements.

In this section, we will focus on the acoustic measurements of formant and duration, since these are robust, as shown previously in § 3.3.1 and § 3.3.2. Because so little is known about the acoustics of vowel F0 and amplitude in Javanese, it is still worth to look at them.

However, since they do not really yield significant results, these are discussed in Appendix B. The organization of the present section is as follows. The acoustic measurements of the F1 and F2 spectral peaks of the penultimate vowels are presented in § 3.4.1, and the durations of these vowels in § 3.4.2. I briefly summarize the results in § 3.4.3.

3.4.1 Vowel formants

To acoustically analyze whether Javanese vowels undergo vowel harmony, penultimate vowels followed by a final CV syllable are compared to those followed by a final CVC syllable. If the formants of the same vowel in the penultimate syllables are comparable whether the final syllable is a CV or a CVC, we would predict that the penultimate vowels do not undergo vowel harmony. If the vowel in the penultimate syllable followed by a final CVC syllable is lower and/or more centralized (especially for the non-low vowels) as compared to when followed by a final CV syllable, we would predict that the penultimate vowel undergoes vowel harmony.

The F1/F2 measurements of penultimate vowels for the Central Javanese speakers are presented in Figure 3.12. In the graph here, the target vowels (i.e. penultimate) are underlined. For example, the penultimate vowel in C**i**Ci# is compared with that in C**i**CiC#.

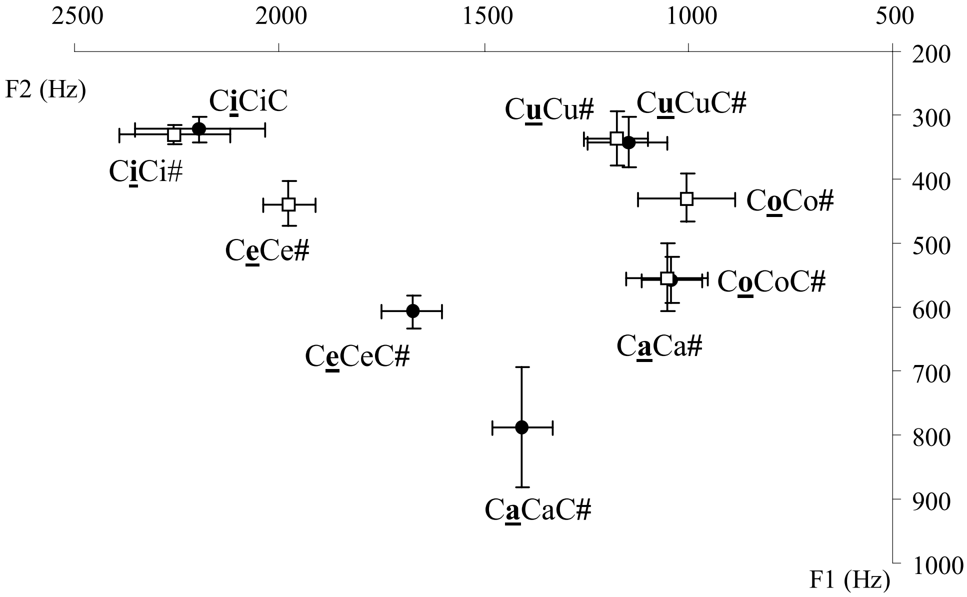


Figure 3.12: Mean F1/F2 values (in Hz) of Javanese penultimate vowels preceding open vs. closed final syllables for the Central Javanese speakers

As shown in the graph above, the high vowels in the penultimate syllable followed by an open syllable, C**i**Ci# and C**u**Cu#, greatly overlap with these vowels followed by a closed syllable, C**i**CiC# and C**u**CuC#. Consequently, the high vowels in the penult in C**i**CiC# and C**u**CuC# are higher than the mid vowels in the penult in C**e**Ce# and C**o**Co#, respectively. In addition, the penultimate /e/ in CVCVC form is relatively more centralized than in CVCV form, while the penultimate /o/ is similar in backness in CVCVC vs. CVCV forms. The penultimate /a/ in the CVCV form is higher and more peripheral in the acoustic space than in the CVCVC form. In fact, it overlaps in the acoustic space with penultimate /o/ followed by a final CVC.

Statistically, the differences between vowels in a penultimate syllable followed by a CV vs. a CVC final syllable are significant for the mid and low vowels ($p < .05$) , but not for the high vowels. As we would expect, the differences between the penultimate /a/ in CaCa# vs. the penultimate /o/ in CoCoC#, of which the F1/F2 mean values are practically the same, are not statistically significant.

These results suggest that for the Central Javanese speakers, high vowels in the penult, with their F1/F2 mean values being similar, remain tense whether the following syllable is a CV or a CVC syllable. That is, high vowels in CVCVC word forms do not undergo vowel harmony. The mid and low vowels in the penult, on the other hand, exhibits quite different F1/F2 mean values, depending on whether the final syllable is a CV or a CVC. This suggests that their acoustic realization is determined by the acoustic realization of the same vowel in the final syllable. Thus, these vowels undergo vowel harmony.

I turn now to the F1/F2 measurements of vowels in penultimate syllables for the Eastern Javanese speakers. The results are shown in Figure 3.13.

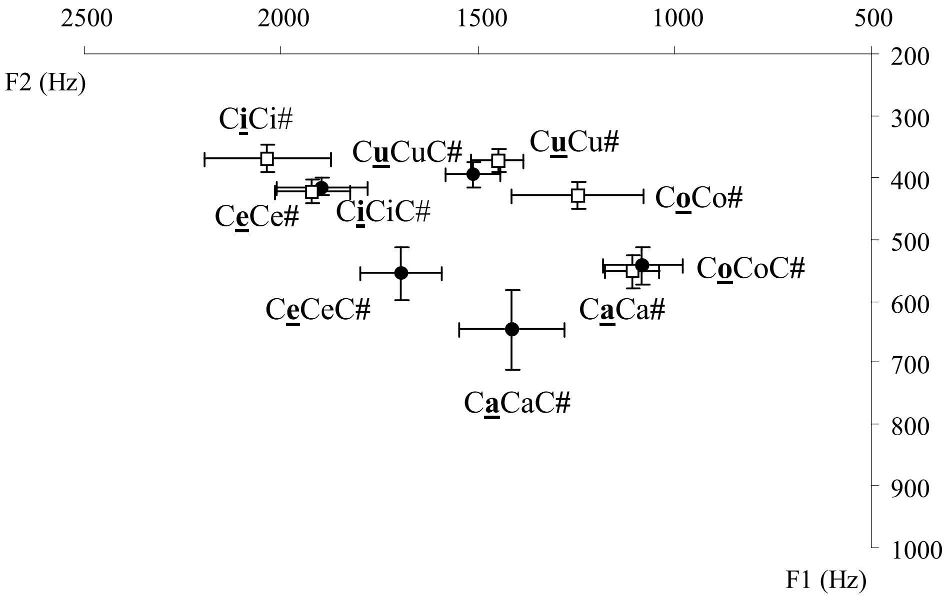


Figure 3.13: Mean F1/F2 values (in Hz) of Javanese penultimate vowels preceding open vs. closed final syllables for the Eastern Javanese speakers

For the high vowels, /i/ in C**i**CiC# is lower and more centralized in the acoustic space as compared to /i/ in C**i**Ci#; /u/ in C**u**CuC# is slightly lower and more centralized than its counterpart in C**u**Cu#. For the mid vowels, /e/ in C**e**CeC# is lower and more centralized than /e/ in C**e**Ce#. The mid vowel /o/ in C**o**CoC# is lower than /o/ in C**o**Co#, even though the former is also more peripheral than the latter. The low vowel /a/ in C**a**Ca# is higher and more peripheral when compared to /a/ in C**a**CaC#.

The F1/F2 differences of vowels in the penultimate syllable in CVCV vs. in CVCVC word forms are statistically significant for all vowels. When the mean values of F1 and F2 of these vowels are separately analyzed, their differences are also statistically significant for all vowels, even though the differences in F2 values for /u/ is only marginally significant (p = .04).

Comparing the vowels that are impressionistically similar, /i/ in C**i**CiC# overlaps in the acoustic space with /e/ in C**e**Ce#, and /a/ in C**a**Ca# with /o/ in C**o**CoC#. Meanwhile, /u/ in C**u**CuC# is higher and more centralized than /o/ in C**o**Co#. Statistically, the F1/F2 differences are not significant for /i/ in C**i**CiC# vs. /e/ in C**e**Ce#, or for /a/ in C**a**Ca# vs. /o/ in C**o**CoC#. However, the F1/F2 mean difference for /u/ in C**u**CuC# vs. /o/ in C**o**Co# is statistically significant, suggesting that despite being perceived as similar, these back vowels are quite different acoustically.

The overall results here indicate that, consistent with the impressionistic observations, at least for the penultimate vowels in C**i**CiC# and C**a**Ca#, Javanese vowels in penultimate CV syllables undergo vowel harmony for the Eastern Javanese speakers, and that this harmony is determined by the syllable shape of the final syllable. For the vowel /u/, the case is not so straightforward. While impressionistically, it does undergo vowel harmony, the results here do not support this observation. Even though the F1/F2 mean values of /u/ in C**u**Cu# vs. C**u**CuC# are sufficiently different, that one might consider this to be the effect of vowel harmony, the F1/F2 mean value of /u/ in C**u**CuC# is also different from the mean value of /o/ in C**o**Co#. In brief, /u/ in C**u**CuC# is neither like /u/ in C**u**Cu# nor like /o/ in C**o**Co#.

One possible line of argument to account for the case with the penultimate /u/ for the Eastern Javanese speakers is based on the fact that /u/ in C**u**Cu# is different from that in C**u**CuC#. Here one may argue that /u/ undergoes vowel harmony, parallel to the case with the front high vowel /i/. The fact that /u/ in C**u**CuC# is acoustically also different from /o/ in C**o**Co# could be explained in reference to several issues of acoustic and perceptual origin. First, based on the F1/F2 graph of vowels that we have seen so far, /u/ in a closed final syllable is always lower and more centralized than /u/ in open final syllable, for the Central and Eastern Javanese speakers. Second, comparing the lowered /u/ in closed syllables and /o/ in open syllables, the lowered /u/ is always more centralized than /o/ in the acoustic space, for both speaker groups; the height of these two vowels may or may not be similar. The F1/F2 measurement results of the penultimate vowels may simply reflect (or mimic) the pattern of vowels in the final syllables, but to a lesser degree. The third issue concerns the perception of these two vowels (i.e. lax /u/ and tense /o/). Speakers with a certain language background, e.g. Indonesian, Javanese, Sundanese, etc., may perceive Javanese lax /u/ and tense /o/ as similar, given the vowel system in their native language; however, speakers whose native language(s) has a vowel system quite different from Javanese may perceive Javanese lax /u/ and tense /o/ as two different vowels. This is an issue to be considered for future perceptual studies.

Comparing the Central vs. the Eastern speakers of Javanese, the clear difference with respect to vowel harmony is that for the Central Javanese speakers, high vowels in the penult are similar whether the following syllable is CV or CVC; the acoustic realization of the mid and low vowels in the penult, on the other hand, appears to be determined by the syllable shape of the following syllable. For the Eastern Javanese speakers, all vowels in the penult are different acoustically when followed by a CV or a CVC syllable, if the case with /u/ can be considered as parallel with /i/. Thus, vowel harmony applies to all vowels in Eastern Javanese and only to mid and low vowels in Central Javanese.

In the next section, I compare the durations of Javanese penultimate vowels followed by open vs. closed final syllables, for the Central and Eastern speakers of Javanese.

3.4.2 Vowel durations

The vowels in the penult discussed in this section are in bisyllabic words of the forms CVCV and CVCVC. Consequently, the vowels examined here are all in an open syllable. One factor that may influence the duration of these vowels are vowel height, i.e. lower vowels tend to be greater in duration as compared to higher vowels. Another factor that may also play a role is the number of segments in a word, in that the greater the number of segments in a word, the shorter the duration of each segment is. Thus the penultimate vowels in CVCV word forms may be greater in duration than those in CVCVC word forms. With respect to the Javanese vowels, what we might find is that lowered mid vowels for the Central Javanese speakers and lowered high and mid vowels in the penult for the Eastern Javanese speakers are greater in duration as compared to their non lowered counterparts. In addition, the low vowel /a/ in the penult realized as [a] (i.e. when it precedes CaC#) may be greater in duration than when it is realized as [ɔ] (i.e. when it precedes Ca#). However, penultimate vowels in CVCVC forms (i.e. the environment for lowered vowels) may be shorter in duration due to the greater number of segments.

The order of analysis is the following: (a) penultimate vowels of different underlying heights in CVCV and CVCVC word forms, and (b) vowels in the penult preceding CV# vs. CVC#. The mean durations of

Javanese vowels in the penult preceding open vs. closed final syllables, as produced by the Central Javanese speakers, are presented in Figure 3.14.

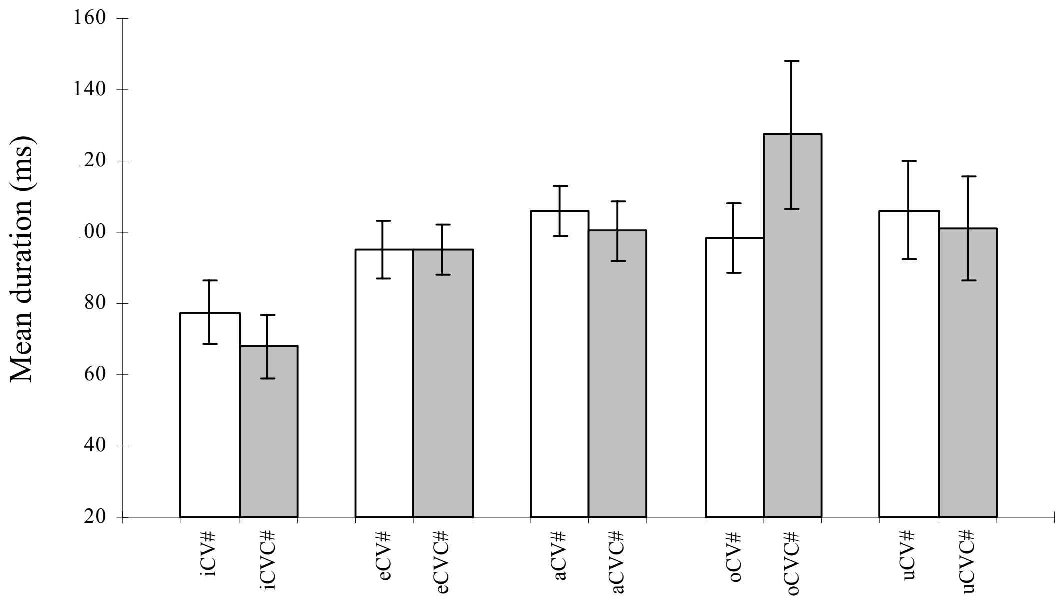


Figure 3.14: Mean durations (in ms) of Javanese penultimate vowels preceding open vs. closed final syllables for the Central Javanese speakers

With respect to vowel height, the mean durations of the penultimate vowels in the CVCV case tend to be less for higher vowels than for lower vowels, except for /u/. In the CVCVC case, the front vowels, /i/ and /e/, and the low vowel /a/ also show this tendency. The mean duration of /u/ is similar to that of /a/. The mean duration of /o/ is surprisingly high, even higher than that of the low vowel /a/. This unusual fact apparently results from the word in which this vowel is embedded: *sorot* ‘beam’. The duration of /r/ in *sorot* is much shorter than that of /t/, e.g. in *tatap*, and this duration difference has perhaps influenced the duration of the preceding /o/, in that the penultimate /o/ in *sorot* is greater in duration as compared to the penultimate /a/ in *tatap*. Due to this, the mean duration of the penultimate /o/ in *sorot*, cannot be included in the comparison of the duration of the penultimate vowels.

Statistical analyses show that the duration differences of vowels with different heights in the CVCV case are statistically significant ($p < .05$) for /i/ vs. all the other vowels, and for /e/ vs. /u/. In the CVCVC case, excluding /o/, these differences are statistically significant only for /i/ vs. all the other vowels.

Comparing vowels preceding CV# vs. CVC# syllables, the mean durations of vowels preceding CV# are greater than preceding CVC# for /i/, /a/, and /u/. The duration differences are: 9.6 ms for /i/, 5 ms for /u/, and 6 ms for /a/. For /e/ in the penult, there is no duration difference whether the following syllable is CV# or CVC#. These differences are statistically significant only for /i/ ($p < .05$). The vowel /o/ is excluded from this comparison, due to the consonant environment problem. Recall that for the Central Javanese speakers, the vowels /e/, /o/ lower when they precede a CVC# and the vowel /a/ preceding a CV# overlaps with /o/ preceding a CVC# in the acoustic space (thus, it is higher than /a/ preceding a CVC#), as shown earlier in Figure 3.12. The duration results for /e/ and /a/ preceding CV# vs. CVC# show that a vowel alternate that is lower (i.e. eCVC# and aCVC#) than its counterpart (i.e. eCV# and aCV#) does not have greater duration.

As mentioned earlier, the number of segments in a word may influence the duration of individual segments. The comparison of the durations of vowels preceding CV# vs. CVC# seems to show that there may be a correlation between the duration of segments and the number of segments in the word. However, the effect seems to be weak. Or, there may be contradictory factors at work.

Following the order of analysis of vowel duration for the Central Javanese speakers, I turn now to the analysis of vowel duration for the Eastern dialect speakers. The mean durations of the penultimate vowels are shown in Figure 3.15.

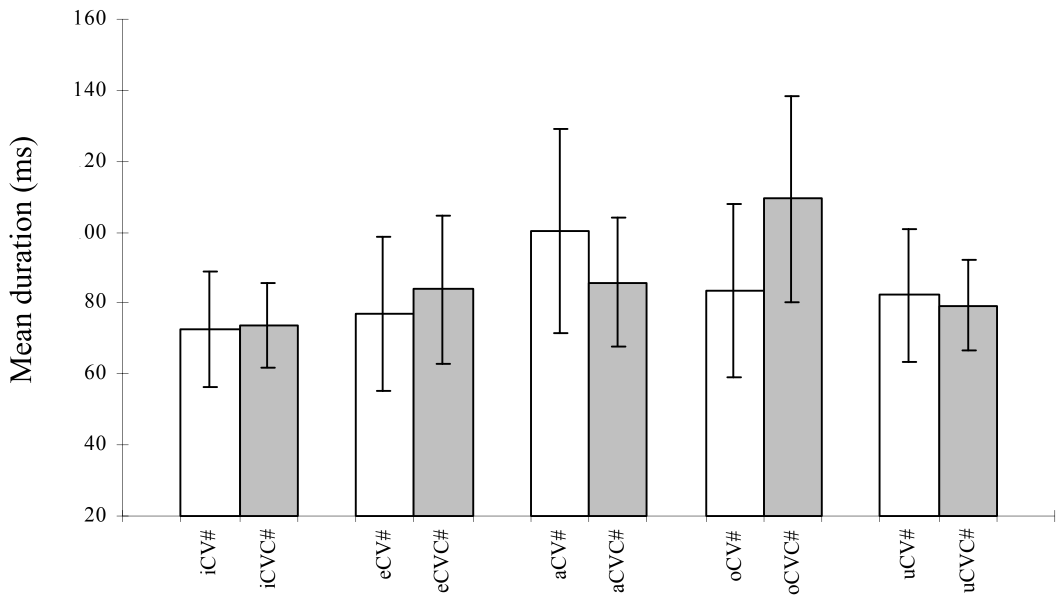


Figure 3.15: Mean durations (in ms) of Javanese penultimate vowels preceding open vs. closed final syllables for the Eastern Javanese speakers

The results here show that high vowels tend to be shorter in duration as compared to lower vowels, in the CVCV case. While the mean differences between the high and the mid vowels in the penult are quite small, these differences are in the expected direction. Excluding /o/, this tendency is also reflected in the CVCVC case, and the mean differences are also quite small. Statistical analyses indicate that these differences are significant ($p < .05$) only for /i/ vs. /a/ in the CVCV case. Comparing the duration measurements for the Central Javanese vs. the Eastern Javanese speakers, the measurements for the former group indicate no systematic pattern while for the latter group, they follow the predicted pattern.

Comparing vowels in the penult preceding a CV# vs. a CVC# syllable, the mean durations for /i/ and /e/ preceding a CV# syllable are lower than preceding a CVC# syllable, with the difference of 1 ms for /i/ and 7 ms for /e/. For /a/ and /u/, the mean durations are greater preceding a CV# syllable than preceding a CVC# one, with the difference of 15 ms for /a/ and 3 ms for /u/. None of these differences reach statistic significance. Recall that it is not possible to compare the mean durations for /o/, due to the consonant environment problem. For the Eastern Javanese speakers, the high and mid vowels in the penult lower when preceding a CVC# syllable, and the low vowel /a/ preceding a CV# overlaps with /o/ preceding a CVC#. The results here indicate that lowered vowels do not necessarily have greater duration as compared to their non lowered counterpart.

The overall results of the duration measurements of vowels in the penult suggest that the timing pattern of Javanese vowels in this position is less than systematic, especially for the Central Javanese speakers. Even when the measurements suggest adherence to the expected pattern, as shown by the measurements of the penultimate vowels preceding CV# syllables for the Eastern Javanese speakers, it is not a robust one. In the next section, I summarize the results presented in § 3.4.1 and § 3.4.2.

3.4.3 Summary of results

In Table 3.5, I present the summary of the acoustic measurements of Javanese vowels in the penultimate syllables, as produced by the speakers from Central and East Java. Bold prints indicate differences among the three speaker groups.

Table 3.5: Summary of the formant structure and duration measurements of Javanese vowels in the penultimate syllables

	Central Javanese	Eastern Javanese
Formant structure	1. Preceding CVC#, mid and mid vowels lower **2. Vowel height:** **- iCVC# ≈ iCV#** **- uCVC# ≈ uCV#** **- aCVC# ≠ aCV#**	1. Preceding CVC#, /i/, mid and low vowels lower; /u/ primarily centralizes **2. Vowel height:** **- iCVC# ≠ iCV#** **- uCVC# ≠ uCV#** **- aCVC# ≠ aCV#**
Vowel duration	**Lower vowels may be greater, similar, or lower in duration as compared to higher vowels**	**Lower vowels may be greater or similar in duration as compared to higher vowels**

Similar to the case of the vowels in final syllables, it seems that the strongest measure for vowel centralization of penultimate vowels as a result of the harmonizing process is vowel formant structure. Other acoustic measurements like vowel duration, fundamental frequency and amplitude (the latter two are presented in Appendix B) do not show a systematic correspondence with the alternation of the penultimate vowels in Javanese. This suggests that the differences in vowel formant structure are quite robust in indicating vowel alternations. Systematic differences in other acoustic characteristics, if any, are more gradient and are weighted less strongly; or these acoustic characteristics are simply not indicative of vowel alternations.

As pointed out previously, the main difference between the two Javanese dialects with respect to vowel harmony is that it applies to all vowels in the Eastern dialect, but that it excludes the high vowels in the Central dialect. The F1/F2 measurements of the penultimate vowels for the Central Javanese speakers concur with this observation. For the Eastern Javanese speakers, the matter is less straightforward: while lowering occurs to both the high vowel, as a result of vowel harmony in CVCVC# cases, the degree to which the back vowel lowers is not acoustically robust.

With this acoustic picture of vowel alternation and vowel harmony in the Javanese of the speakers from Central and East Java, we can now turn to the central question of the influence of the Javanese vowel system on the speech of bilingual speakers. First, I analyze the pattern of the Indonesian vowels as produced by the monolingual Indonesian speakers, and then I compare this pattern with that for the bilingual speakers.

3.5 Acoustic measurements and analyses of word-final vowels in Indonesian

In this section, I examine the results of the acoustic measurements of all the Indonesian vowels (excluding schwa) in the final open and closed syllables, as produced by the monolingual Indonesian speakers and by the bilingual Javanese/Indonesian speakers. The order of presentation of the results is the following. In § 3.5.1, I present the F1/F2 measurements of the three speaker groups: the monolingual Indonesian speakers, the bilingual Central Javanese/Indonesian speakers, and the bilingual Eastern Javanese/Indonesian speakers. In § 3.5.2, I present the mean duration values. The mean F0 values and the mean values of amplitude differences are presented and discussed in Appendix B, since, as with the case in Javanese, they do not contribute robustly to the understanding of these vowels. In § 3.5.3, I summarize the results.

3.5.1 Vowel formants

As discussed earlier, vowels in Indonesian are claimed to not undergo vowel centralization or vowel harmony, except for the mid vowels. With respect to the vowel pattern of the bilingual speakers, what we would expect to see is that if the Javanese pattern prevails then all vowels centralize and harmonize depending on syllable structure; if the Indonesian pattern is the one that prevails instead, then only mid vowels centralize and harmonize. Vowels are first compared based on syllable structure, i.e. CV# vs. CVC#, and then based on their perceived similarity. In Figure 3.16, I present the F1/F2 mean values of the Indonesian vowels by the monolingual Indonesian speakers. Recall that (□) represents open syllables and (●) represents closed syllables.

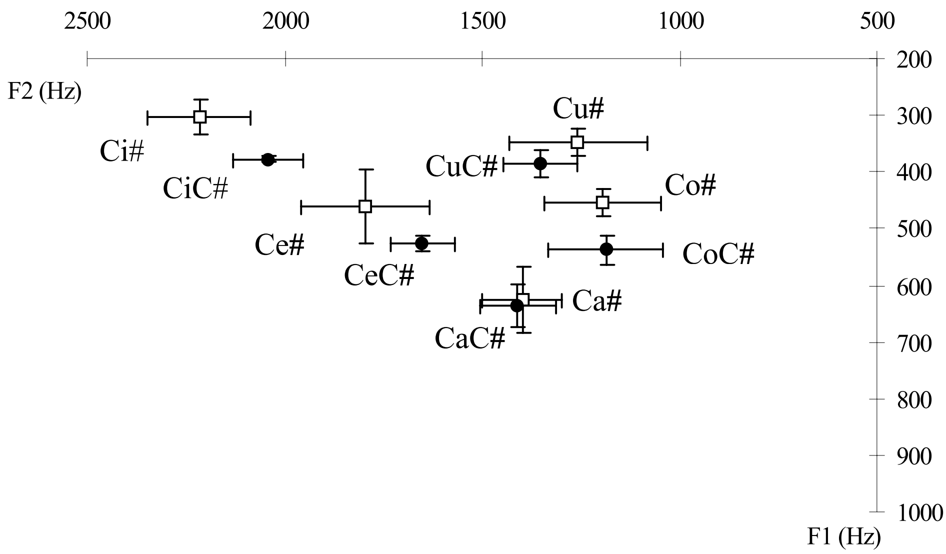


Figure 3.16: Mean F1/F2 values (in Hz) of Indonesian final vowels in open vs. closed syllables for the monolingual Indonesian speakers

For the monolingual speakers, the high and mid vowels are lower in the acoustic space when they are in the final closed syllables when compared to vowels in final open syllables. With respect to the front vowels /i, e/, those in final CVC syllables are also more centralized than those in final CV syllables. For the back vowels, the high vowel /u/ is more centralized in final CVC syllables than in final CV ones, while the mid vowel /o/ in final open and closed syllables have a similar degree of backness. For the low vowel /a/, the difference between this vowel in final CV vs. final CVC syllables is negligible. The differences of vowels in final CV vs. final CVC syllables are statistically significant ($p < .05$) for all vowels, except for /a/. The F1/F2 differences of the back vowels /u/ and /o/ reach statistical significance primarily due to F1 mean differences (i.e. height). The F1/F2 mean values for the Indonesian vowels in final CV and CVC syllables presented here are generally comparable to the values for these vowels produced in isolation and embedded in CVC monosyllabic words, respectively, as presented in van Zanten's study (1989).

The results here suggest that despite the claim that there is no (impressionistic) quality difference for Indonesian high vowels in open vs. closed final syllables, they are acoustically different. One factor that may result in this divergence is consonant environment, which has commonly been found to affect vowel formants (e.g. House and Fairbanks, 1953), including in the Indonesian of the Sundanese and the Toba Batak bilingual speakers (van Zanten, 1989).

I turn now to the production of Indonesian vowels by the bilingual speakers from Central Java. The F1/F2 measurements of these vowels are presented in Figure 3.17.

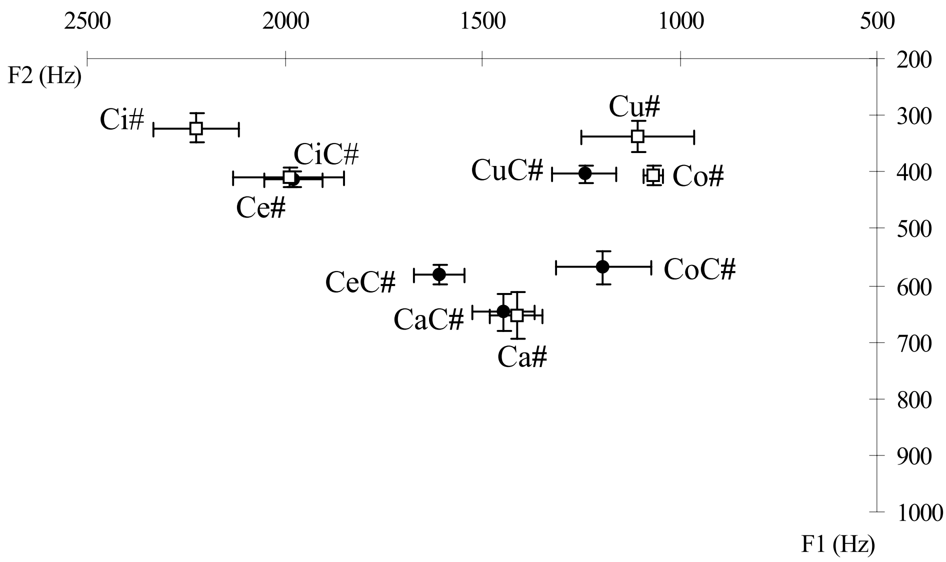


Figure 3.17: Mean F1/F2 values (in Hz) of Indonesian final vowels in open vs. closed syllables for the bilingual Central Javanese/Indonesian speakers

As the result shows, all non-low vowels in final CVs are lower and more centralized than their counterpart in final CVCs. The low vowel /a/ in final CVs and its counterpart in final CVCs overlap. Statistical analysis shows that the F1/F2 differences between vowels in final CV vs. final CVC syllables are significant ($p < .05$), except for /a/. For /u/, however, the differences of the F2 values in CV# vs. CVC# are not significant.

For vowels that are judged similar, /i/ in CiC# overlaps with /e/ in Ce#. /u/ in CuC# and /o/ in Co# are of similar height, but the former is more centralized than the latter. In the Indonesian of the Javanese/ Indonesian bilingual speakers, /a/ in Ca# is impressionistically not similar to /o/ in CoC#, which is the case in Javanese. This is consistent with the results of the F1/F2 measurements, since /a/ in Ca# overlaps with /a/ in

CaC#, and not with /o/ in CoC#. The F1/F2 differences for vowels in Ce# vs. CiC# are statistically not significant. They are significant ($p < .05$) for the vowels in Co# vs. CuC#, even though these are due to differences in F2, and not F1. As mentioned earlier, the F1/F2 differences of Ca# vs. CaC# are not significant; they are significant, however, for Ca# vs. CoC#. These results are similar to those found by van Zanten (1989), even though in her studies, /u/ in CuC# and /o/ in Co# in the Indonesian of one of the bilingual Javanese/Indonesian speakers overlaps in the acoustic space. Here, they are of similar height but different backness.

I turn now to the production of Indonesian vowels by the bilingual speakers from East Java. The F1/F2 measurements are shown in Figure 3.18.

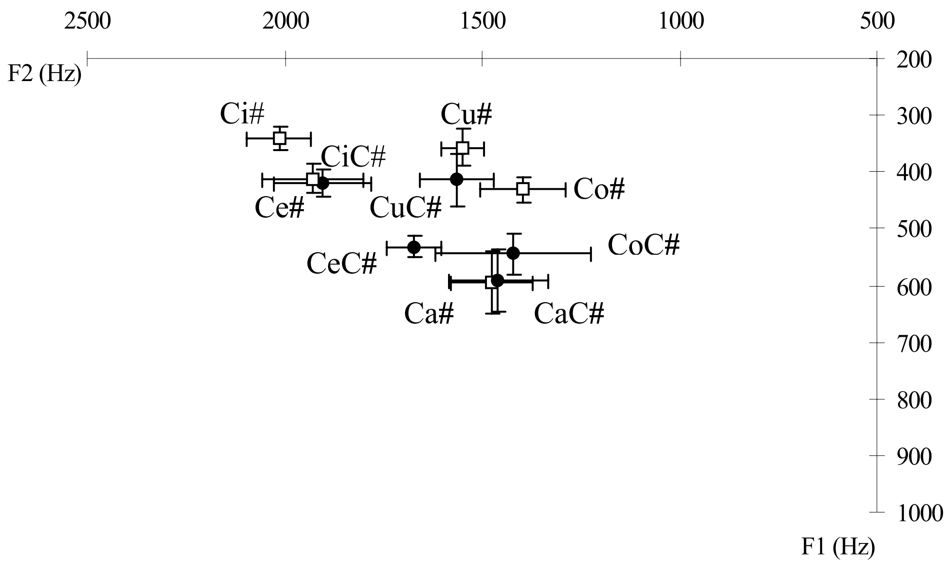


Figure 3.18: Mean F1/F2 values (in Hz) of Indonesian final vowels in open vs. closed syllables for the bilingual Eastern Javanese/Indonesian speakers

It is interesting to note that the acoustic space for vowels in the Indonesian of the Eastern Javanese speakers is small, similar to the acoustic space for vowels in the Javanese of these speakers. Comparing the high vowels for these speakers, those in final CVC syllables are lower and more centralized than those in final CV syllables. The mid vowels in final CVC syllables are lower than their counterpart in final CV syllables, and this is more so for /e/ than for /o/. For the back vowels /u, o/, those in CVC# are only slightly centralized relative to their counterparts in CV#. The low vowels in Ca# and in CaC# overlap. Statistical analysis indicates that the F1/F2 differences of vowels in final CV vs. CVC syllables are significant for all vowels, except for /a/. Looking at the F1 and F2 differences separately, excluding /a/, the F1 differences are statistically significant for all vowels and the F2 differences are statistically significant only for the front vowels.

For vowels that are impressionistically similar, /i/ in CiC# and /e/ in Ce# practically overlap. /u/ in CuC# is more centralized but of similar height relative to /o/ in Co#. Unlike the low vowel in Javanese for the Eastern Javanese speakers, the Indonesian low vowel in Ca# is distinct from the mid vowel in CoC# for these speakers. Statistical analyses indicate that the F1/F2 differences between the vowels in CiC# vs. Ce# are not significant. The differences between the vowels in Co# vs. CuC# are significant, even though they are mainly due to the differences in F1 values. The differences between the vowels in Ca# and CoC# are significant, but not for those in Ca# vs. CaC#, as mentioned previously.

To summarize, the F1/F2 measurements for the bilingual speakers here show that the acoustic realization of the Indonesian non-low vowels in final open vs. closed syllables, for the bilingual Javanese/Indonesian speakers, mirror the acoustic realization of the Javanese non-low vowels in final open vs. closed syllables for these speakers, shown earlier in Figures 3.4 and 3.5. This is particularly the case for the high vowels, where /i/ in CiC# 'merges' with /e/ in Ce#, and /u/ in CuC# is of similar height as /o/ in CoC#, in the acoustic space. This result supports the impressionistic observation that bilingual speakers of Javanese origin have a Javanese 'accent' in their Indonesian with respect to vowel quality. Note, however, that the influence of vowel alternation in Javanese only affects the high vowels; the acoustic realization of the Indonesian low vowel /a/ by the bilingual speakers reflects the Indonesian pattern, i.e. there is no [a]-[ɔ] alternation governed by syllable structure. Thus, the manifestation of Javanese vowel pattern in the Indonesian of the bilingual speakers affects only a subset, rather than the whole of the vowel inventory.

Recall that the Indonesian high vowels also lower in final CVC in the Indonesian for the monolingual speakers, shown in Figure 3.16. However, one can see that there are systematic differences in the Indonesian vowels as produced by the monolingual speakers vs. those produced by the bilingual speakers. The mid vowels in final CV syllables are relatively lower in the acoustic space for the monolinguals than for the bilinguals: the F1 mean values are 462 Hz for the monolingual speakers, and 409 Hz and 412 Hz for the bilingual speakers from Central and East Java, respectively. In addition, the lowered high vowels in final CVC syllables 'crowd' into the space of the mid vowels in final CVs for the bilingual speakers, but not for the monolinguals. This is especially the case for the front vowel, while for the back vowel, height (i.e. F1) is more affected than backness (i.e. F2).

Based on these findings, one may conclude that the lowering of the Indonesian high vowels for the monolingual Indonesian speakers and the bilingual Javanese/Indonesian speakers is due to syllable structure, namely the presence and absence of the final consonant. A question that arises from these findings is what the nature is of the vowel lowering for the monolingual vs. the bilingual speakers. I discuss this issue in § 3.7.

In the next section, I turn to the analysis of the durations of Indonesian vowels in final CV vs. final CVC syllables, as produced by the three speaker groups.

3.5.2 Vowel durations

As with the case in Javanese and in other languages, we would expect to see the effect of syllable structure on the duration of vowels, in that vowels tend to be shorter in duration in closed syllables relative to when they are in open syllables. The mean durations of Indonesian vowels in final syllables as produced by the monolingual Indonesian speakers are presented in Figure 3.19.

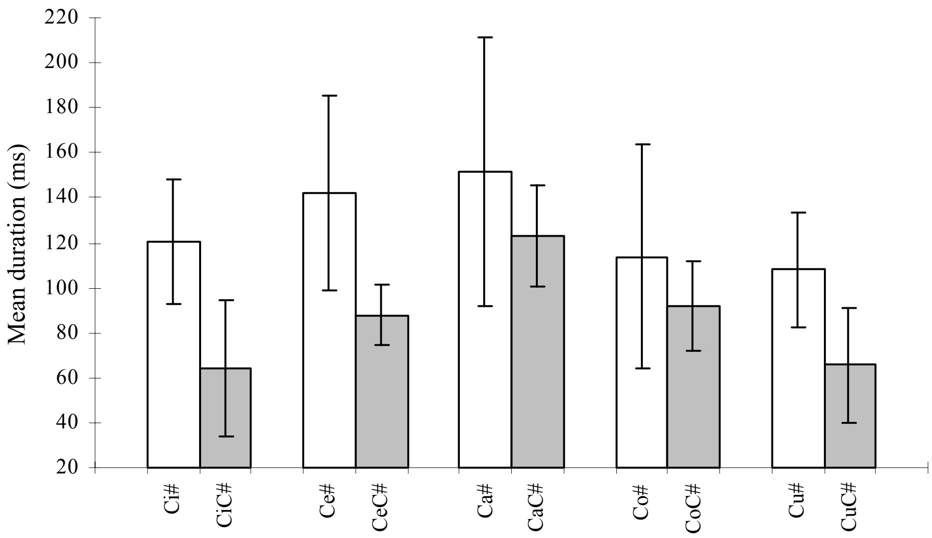


Figure 3.19: Mean durations (in ms) of Indonesian final vowels in open vs. closed syllables for the monolingual Indonesian speakers

Following the order of presentation carried out in previous sections, I analyze (a) the durations of vowels in open vs. closed syllables, then (b) the durations of vowels in the same syllable type (e.g. Ci# vs. Ce#), and finally (c) the durations of the lowered high vowels relative to those of the tense mid vowels.

As shown in Figure 3.19, the mean durations of vowels in CV# are greater than in CVC#, for all vowels. The duration differences range from 22 ms for /o/ to 56 ms for /i/, with the range of ratios from 1:1.2 to 1:1.9, respectively. Statistical analysis indicates that these differences are significant for /i, e, u/, but not for /o, a/.

Comparing different vowels in the same syllable type, the results show that the low vowels tend to have greater duration than the higher vowels, in CV# and in CVC#. Note, however, that /i/ in Ci# has a slightly greater duration (6 ms) than /o/ in Co#. In the CV cases, the differences of vowel mean durations are statistically not significant. In the CVC cases, these differences are statistically significant for the vowels in CiC# vs. CeC#, CiC# vs. CuC#, CeC# vs. CoC#, and CeC# vs. CuC#. They are marginally significant for CiC# vs. CoC# and CoC# vs. CuC# (p = .04).

These results also show that the lowered high vowels in CVC# are seen to have smaller duration as compared to the tense mid vowels in CV#. The mean differences of 78 ms for /i/ vs. /e/ and 48 ms for /u/ vs. /o/ reach statistic significance. This further suggests that in the Indonesian of the monolingual speakers, syllable shape determines the duration of a vowel in a final syllable.

Next I turn to the duration measurements of the Indonesian vowels in final syllables as produced by the bilingual speakers from Central Java. The results are shown in Figure 3.20.

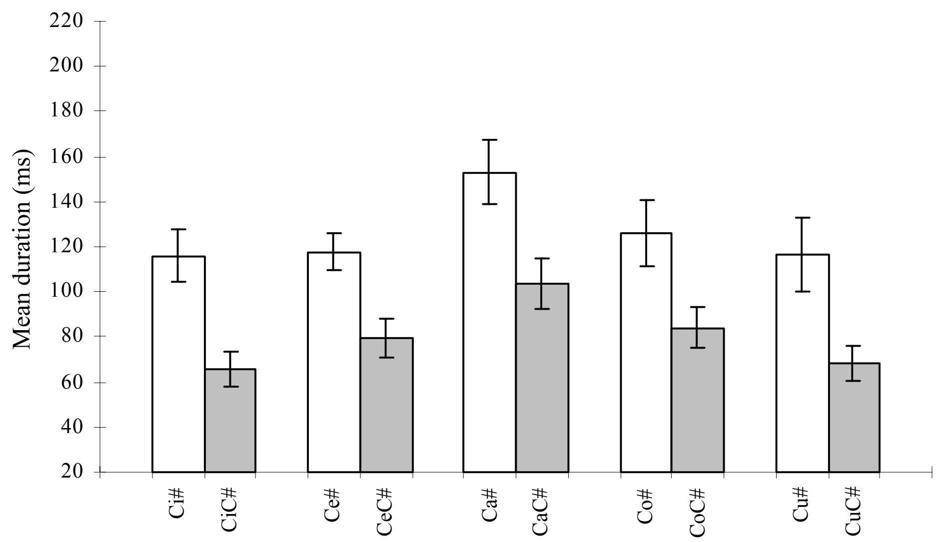


Figure 3.20: Mean durations (in ms) of Indonesian final vowels in open vs. closed syllables for the bilingual Central Javanese/Indonesian speakers

Similar to the case for the monolingual speakers, Indonesian vowels are greater in duration in a CV syllable than in a CVC syllable. The differences range from 39 ms for /e/ to 50 ms for /i/, with the range of ratios from 1:1.5 to 1:1.8 respectively. These differences are statistically significant for all vowels.

Comparing vowels in the same syllable type, in the CV syllables, the mean duration of the high back vowel is smaller than that of the mid back vowel, but the mean durations for the high and mid front vowels are comparable. The mean duration of the low vowel is the greatest when compared to the other higher vowels. In the CVC syllables, higher vowels are seen to have smaller mean durations relative to the lower vowels. For the CV cases, the mean duration differences between Ca# and the other vowels are statistically significant. For the CVC cases, these differences are also statistically significant, except CiC# vs. CuC# and CeC# vs. CoC#; in other words, the mean differences are not significant between the high vowels and between the mid vowels.

Comparing the vowel pairs that are impressionistically similar, the mean durations of /i/ in CiC# and /u/ in CuC# are smaller than those of /e/ in Ce# and those of /o/ in Co#, respectively. These differences reach statistic significance. This indicates that despite their impressionistic similarity, the duration of these vowels are determined by syllable structure.

Lastly, I present the mean durations of Indonesian vowels in CV vs. CVC syllables as produced by the bilingual speakers from East Java. The results are shown in Figure 3.21.

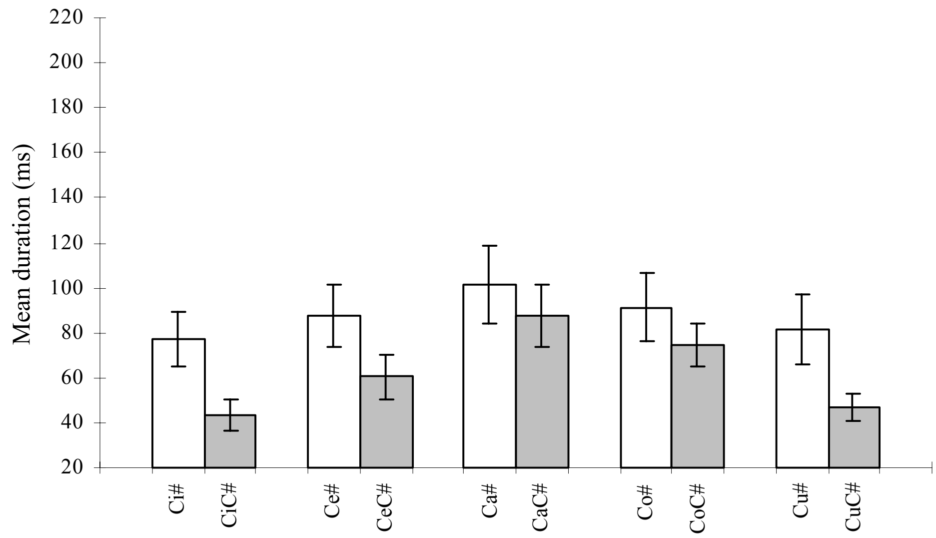


Figure 3.21: Mean durations (in ms) of Indonesian final vowels in open vs. closed syllables for the bilingual Eastern Javanese/Indonesian speakers

As shown here, the mean durations of final vowels in the Indonesian for the Eastern Javanese speakers are quite short. This might explain the small acoustic space for these vowels, as shown in Figure 3.18. As with the case for the other two speaker groups, the mean durations of Indonesian vowels in final syllables are determined by the shape of the syllable, in that they are greater for the CV cases than for the CVC cases. The differences range from 13 ms for /a/ to 34 ms for /u/, with ratios ranging from 1:1.2 to 1:1.7, respectively. Statistically, these differences are significant ($p < .05$) for the vowels, even though only marginally for /a/ ($p = .04$).

Comparing vowels in the same syllable type, in the CV# syllables, the mean durations for lower vowels are greater than for the higher ones. This is also the case in the CVC# syllables. Statistically analysis indicates that for the CV cases, the mean differences are statistically significant

($p < .05$) for Ci# vs. Ca# and for Cu# vs. Ca#; for the CVC cases, these differences are statistically significant for the vowels, except for those in CiC# vs. CuC#.

For vowels that are impressionistically similar, the mean durations of /i/ in CiC# and /u/ in CuC# are smaller than /e/ in Ce# and /o/ in Co#, respectively. These differences are statistically significant ($p < .05$), and again they indicate that syllable shape influences the duration of a vowel.

To summarize the duration measurements in this section, for all three groups of speakers, vowels in final open syllables are shown to have greater duration than those in final closed syllables. In addition, the lower vowels tend to have greater duration than the higher vowels, in both open and closed final syllables. The findings also show that the durations of the Indonesian /i/ in CiC# vs. /e/ in Ce# and /u/ in CuC# vs. /o/ in Co# are determined by the shape of the syllable. This is the case for all three speaker groups. Recall that, for the bilingual speakers, these are the vowel pairs that are impressionistically similar; acoustically, these vowel pairs are at least of similar height, as the results in Figures 3.21 and 3.22 show. These findings suggest that the impressionistic similarity of these vowel pair is mainly due to their similarity in quality, and that vowel duration does not play a role in enhancing this similarity. Rather, vowel duration is an acoustic effect resulting from syllable shape.

In the following section, I present the overall results of vowel formant structure and vowel duration in the Indonesian of the monolingual and the bilingual speakers.

3.5.3 Summary of results

In the Table 3.6, I compare the summarized results of the measurements for Indonesian vowels in final syllables, as produced by the monolingual Indonesian and the bilingual Javanese/Indonesian speakers. Bold prints indicate differences among the speaker groups.

Table 3.6: Summary of the acoustic measurements of Indonesian vowels in the final syllables

	Monolingual Indonesian	Bilingual Central Javanese	Bilingual Eastern Javanese
Formant structure	1. Except for /a/, vowels lower in final CVCs **2. Vowel height: CiC# ≠ Ce# CuC# ≠ Co#**	1. Except for /a/, vowels lower in final CVCs **2. Vowel height: CiC# ≈ Ce# CuC# ≈ Co#**	1. Except for /a/, vowels lower in final CVCs **2. Vowel height: CiC# ≈ Ce# CuC# ≈ Co#**
Vowel duration	1. Vowels in final CVs are longer than those in final CVCs 2. High vowels tend to be shorter than lower vowels	1. Vowels in final CVs are longer than those in final CVCs 2. High vowels tend to be shorter than lower vowels	1. Vowels in final CVs are longer than those in final CVCs 2. High vowels tend to be shorter than lower vowels

With respect to vowel formant structure, the main difference between the monolingual Indonesian speakers and the bilingual speakers is in the height of the vowels perceived to be similar. For the bilingual speakers, /i/ and /u/ in CVC# are of similar height as /e/ and /o/ in CV#, respectively. For the monolingual speakers, even though /i/ and /u/ in CVC# lower, they are higher in the acoustic space than /e/ and /o/ in CV#, respectively, and the lowered high vowels and the non lowered mid vowels are still quite distinct from each other.

The combined effect of differences in formant structure and in duration of vowels in CV vs. CVC syllables may enhance the quality differences for the high and mid vowels. Perceived quality differences between vowels resulting from duration difference have been found in a closely related language, e.g. Madurese (Cohn and Lockwood, 1994). In the Indonesian of the bilingual speakers (and for the cases in Javanese as well), vowels are shorter in duration in CVC# than in CV#. It is possible that, for example, /i/ in CVC# and that in CV# are perceived as different partly due to differences in duration. In addition, /i/ in CVC# and /e/ in CV# completely 'merge' in the acoustic space. However, this line of argument view could be complicated by the fact that the duration of /i/ in CVC# is shorter than that of /e/ in CV#. The extent to which vowel duration contributes to vowel quality differences in Indonesian (and Javanese) needs further investigation.

3.6 Acoustic measurements and analyses of penultimate vowels in Indonesian

In this section, I present and analyze the acoustic measurements of five of the six Indonesian vowels in the penultimate (open) syllables preceding final open vs. closed syllables, for the monolingual Indonesian speakers and the bilingual speakers from Central and East Java. The shape of the target words is either $CV_1CV_2\#$ or $CV_1CV_2C\#$, where $V_1 = V_2$. The F1/F2 measurements of these vowels are presented in § 3.6.1, and their durations are presented in § 3.6.2. The overall F0 values and the mean values of amplitude differences of these vowels are presented and discussed in Appendix B. In § 3.6.3, I summarize the results for F1/F2 and duration measurements.

3.6.1 Vowel formants

As described previously, vowels in Indonesian undergo vowel harmony. The main evidence comes from the patterning of the mid vowels in CV_1CV_2(C) words, where $V_1 = V_2$. When both penultimate and final vowels are either /e/ or /o/, they surface as [ɛ] and [ɔ], respectively, in both syllables. In CVCV words, these vowels surface as [e] and [o] in both syllables. For the high and low vowels in CVCV and CVCVC words, they are impressionistically similar in the penultimate and final syllables. See the data listed earlier in (5-6), for examples.

In the production of the Indonesian vowels in the penultimate syllables in the CVCV words, the monolingual and bilingual speakers are predicted to be similar, in that the penultimate vowels would be acoustically similar to the final ones; that is, the penultimate vowels would remain tense for all three speaker groups. In the CVCVC words, on the other hand, the speakers are predicted to show some differences. We anticipate the monolingual speakers and the bilingual speakers from Central Java to show similarity, in that high vowels in the penult would be realized as tense. For the bilingual speakers from East Java, however, we would predict that the high vowels in the penult would be realized as lax, resulting from the vowel harmony effect; this would be the case if the influence of the vowel patterning in the Eastern Javanese dialect is manifested in the Indonesian of these speakers.

Given the impressionistic observations, we would expect to see that the formants of a high or a low vowel in the penult are comparable whether the final syllable is a CV or a CVC for the monolingual speakers and the bilingual speakers from Central Java; when the vowel in the penult is mid, we would expect to see its formants preceding a final CV vs. CVC to be different showing the effect of vowel harmony. For the bilingual speakers from East Java, we may see the formants for a non-low vowel (i.e. high or mid) to be different when preceding a final CV vs. CVC.

I analyze first the F1/F2 measurements of the Indonesian vowels in the penult as produced by the monolingual speakers. The results are shown in Figure 3.22.

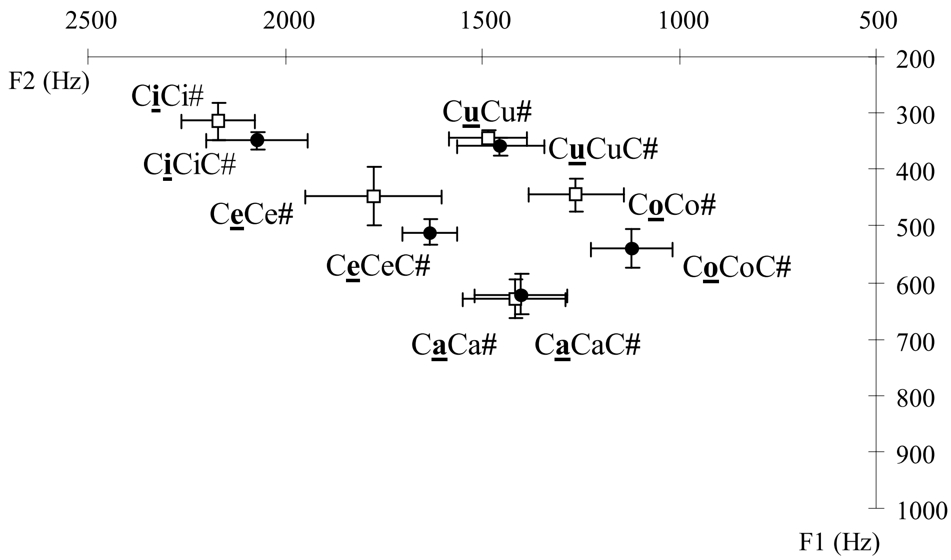


Figure 3.22: Mean F1/F2 values (in Hz) of Indonesian penultimate vowels preceding open vs. closed final syllables for the monolingual Indonesian speakers

As shown here, /u/ preceding Cu# vs. /u/ preceding CuC# overlap in the acoustic space. This is also the case for /a/. /i/ preceding Ci# is higher and more peripheral than /i/ preceding CiC#. For the mid vowels, /e/ preceding CeC# is lower and more centralized than its counterpart preceding Ce#, while /o/ preceding CoC# is lower and more peripheral than its counterpart preceding Co#. Statistical analysis indicates that the F1/F2 differences of a vowel preceding a CV# vs. a CVC# are significant for /i/, /e/, and /o/, and marginally significant for /u/ ($p = .04$), primarily due to the difference in height ($p = .01$) but not the difference in backness. The F1/F2 differences for /a/ are not significant.

The results here seem to indicate that the shape of the final syllable plays a role in determining whether the high and the mid vowels are lowered (and also centralized for the front vowels). Based on the impressionistic observation, only the penultimate mid vowels in CVCVC words lower, as a result of vowel harmony. Thus, the lowering of the Indonesian high vowels in the penult for the monolingual speakers is unexpected.

There are at least two possible accounts to explain this acoustic result. In one account, the high vowel lowering in the penult seen here may be triggered by the high vowel lowering in the final position. We have seen that Indonesian high vowels lower in final CVC syllables for the monolingual speakers, as shown earlier in Figure 3.16. If this process is phonological, then we have a case of vowel harmony affecting high vowels, as well as mid vowels, in the Indonesian of the monolingual speakers.

In another account, it is possible that this lowering is a phonetic process of anticipatory coarticulation, whereby the degree of height and/or backness of a vowel is influenced by the degree of height and/or backness of either the preceding (carryover) or the following (anticipatory) vowel. This phenomenon has been found in languages like Swedish, Russian, English, Spanish, Swahili, Shona, etc. (Ohman, 1966; Manuel and Krakow, 1984; Recasens, 1987; Manuel, 1990; Choi and Keating, 1991), in which a vowel is lower in the acoustic space when preceding a low vowel than when preceding a high vowel. In Indonesian, if the lowering is a coarticulatory effect, the high vowel in the penult lowers in agreement with the lowering of the high vowel in the closed final syllable. So, in a sense, the trigger for lowering in the phonological account and in the phonetic account would be the same, but we would expect to see a difference in magnitude. Beddor and Yavuz (1995) find that anticipatory vowel coarticulation in Turkish exhibits greater effect than carryover vowel coarticulation. In this language, vowel harmony proceeds from left to right.

I turn now to the Indonesian vowels in the penult, as produced by the bilingual speakers from Central Java. The F1/F2 measurement results are presented in Figure 3.23.

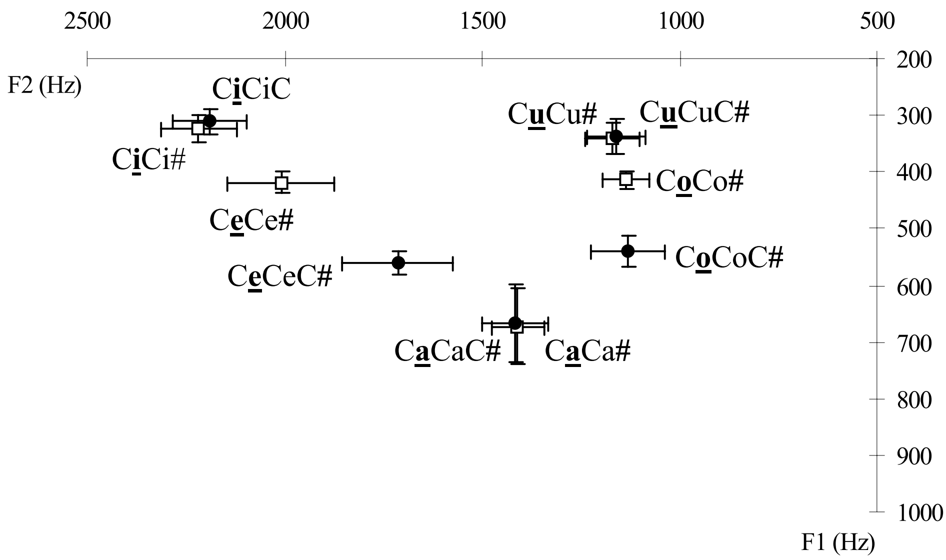


Figure 3.23: Mean F1/F2 values (in Hz) of Indonesian penultimate vowels preceding open vs. closed final syllables for the bilingual Central Javanese/Indonesian speakers

As shown here, the penultimate vowels preceding a CV# vs. a CVC# practically overlap for the vowels /i/, /u/, and /a/. For the mid vowels, those preceding CVC# are lower in the acoustic space. /e/ preceding CeC# is also more centralized than its counterpart preceding Ce#. Statistical analysis indicates that the F1/F2 differences are significant ($p < .05$) for the mid vowels /e/ and /o/, but not for /i/, /u/, and /a/. These results support the impressionistic observation wherein only mid vowels undergo vowel harmony, in the Indonesian for the bilingual speakers from Central Java. In addition, comparing the F1/F2 values of Indonesian vowels for the bilingual speakers from Central Java in Figure 3.23 with those of Javanese vowels for these speakers (see Figure 3.10), one may argue that the realization of Indonesian high vowels in the penultimate syllables reflects the pattern of Javanese high vowels in the penultimate syllables. Comparing the Indonesian high vowels for the monolingual and the bilingual Central Javanese speakers, we predicted no difference; but strikingly, the laxing seen in the Indonesian for the monolingual speakers does not occur in the Indonesian for the bilingual speakers.

Turning to the pattern of Indonesian penultimate vowels in CVCV vs. CVCVC words by the bilingual speakers from East Java, the F1/F2 measurement results are presented in Figure 3.24. Here, if the influence of Javanese is manifested on Indonesian, we would expect to see the vowel harmony affecting not only the mid vowels but the high vowels as well.

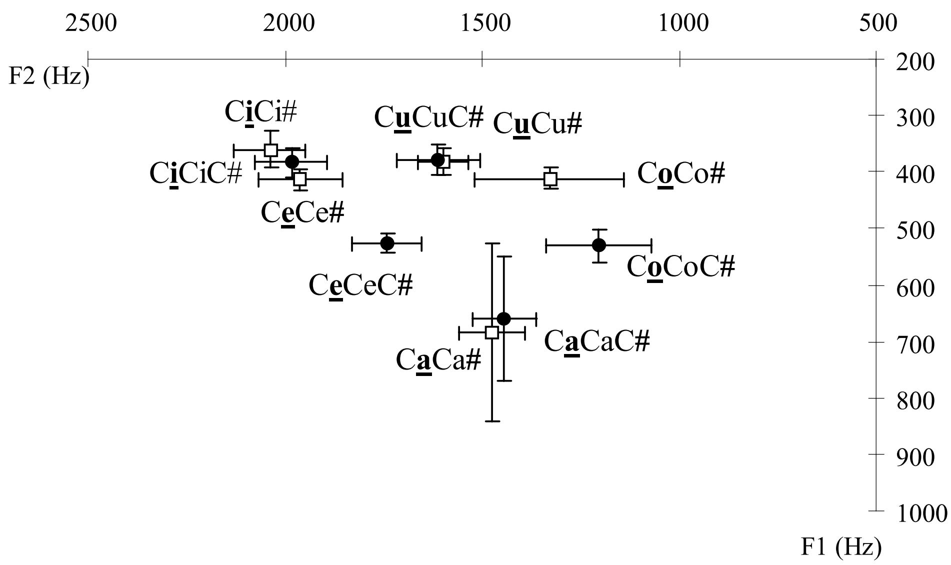


Figure 3.24: Mean F1/F2 values (in Hz) of Indonesian penultimate vowels preceding open vs. closed final syllables for the bilingual Eastern Javanese/Indonesian speakers

For the high vowels, /i/ preceding CiC# is slightly lower and centralized than /i/ preceding Ci#; /u/ preceding CuC# and that preceding Cu# overlap in the acoustic space. For the mid vowels, those preceding CVC# are lower than those preceding CV# in the acoustic space. For /e/, the lowered alternate is also centralized, while for /o/, it is more peripheral. For the low vowel, /a/ preceding CaC# and preceding Ca# overlap[8]. The statistical analysis indicates that the F1/F2 differences for these vowels preceding a CV# vs. a CVC# are significant ($p < .05$) only for the mid vowels, and is marginally significant for /i/ ($p = .05$). Looking at the F1 and F2 values separately for /i/, the mean differences is marginally significant for F1 (or height) ($p = .06$) and is not significant for F2 (or backness. For /u/ and /a/, the F1/F2 differences are statistically not significant.

Recall that for the Eastern Javanese speakers, /i/ preceding CiC# and /u/ preceding CuC# have been observed to undergo vowel harmony and are impressionistically similar to the same vowel in the final syllable. We have seen earlier that in the final closed syllables, /i/ and /u/ lower and /i/ overlaps with /e/ in final open syllables, in the acoustic space. If /i/ and /u/ in the penult undergo vowel harmony, we would expect them to lower in the acoustic space when followed by CiC# and CuC#, respectively. The F1/F2 measurements in Figure 3.24 show that /i/ preceding CiC# and /e/ preceding Ce# are close to each other in the acoustic space, while /u/ preceding CuC# and /o/ preceding Co# are quite far apart. Statistic

[8] Note that there is a great value range of F1 for /a/ and of F2 for /o/, as shown in Figure 3.24. This is due to speakers' variability; e.g. the F1 value range of /a/ is about 500 Hz for one speaker and in the vicinity of 800 Hz for another speaker. Interestingly, this variability appears only on the vowels /a/ and /o/.

analysis indicates that the F1/F2 difference for the /i/-/e/ pair is significant ($p < .05$), primarily due to height ($p = .01$) but not backness. For the /u/-/o/ pair, the F1/F2 difference is statistically significant, due to both the difference in height and in backness.

These results show that if vowel harmony in Eastern Javanese is manifested in the Indonesian of the bilingual speakers from East Java, its acoustic realization is not straightforwardly obvious. Several issues they present are the following. First, /i/ preceding CiC# is lower and more centralized than preceding Ci#, but it is not as low and only almost as centralized as /e/ preceding Ce#; one may argue that this is a case of anticipatory coarticulation, rather than a case of vowel harmony. Second, /u/ preceding CuC# and preceding Cu# overlap in the acoustic space; this is the opposite of what we would expect if vowel harmony were to occur.

The degree of high vowel lowering in the Indonesian of the Eastern Javanese seems comparable to the lowering in the Indonesian of the monolinguals. There are two possible (opposing) positions that one could choose to take, to account for high vowel lowering in Indonesian. In one position, one may conclude that the high vowel lowering in the Indonesian of the Eastern Javanese speakers is expected, showing the manifestation of Eastern Javanese influence in their Indonesian. In addition, the high vowel lowering in the Indonesian of the monolingual speakers would contradict the impressionistic observation. In the other position, one may consider the possibility that the lowering in the Indonesian of the monolinguals has been overlooked, and when it occurs in the Indonesian of the Eastern Javanese speakers, it is wrongly attributed to an influence from Eastern Javanese.

These results may also show the manifestation of extra-linguistic factors, such as inaccurate impressionistic observations, and speakers' attitude towards formal vs. informal communication and thus the appearance or disappearance of certain (phonological) features. If the impressionistic observations are inaccurate regarding the manifestation of vowel harmony in the Indonesian of the bilingual speakers from East Java, the results here may show that the lowering of /i/ preceding CiC# is a case of coarticulation and the overlapping of /u/ preceding Cu# and preceding CuC# is the expected pattern. (The acoustic difference between /i/ and /u/ may be accounted for by the fact that there is more 'space for variation' for front vowels than for back ones.) Being a bilingual speaker of Eastern Javanese/Indonesian myself, I argue that speakers' attitude in general towards the degree of formality of the communication would determine the presence and absence of certain grammatical features during speech events. For the Eastern Javanese speakers (at least for some of them), in particular, this may mean that vowel harmony does not apply to the high vowels. To support this argument, further acoustic studies would need to be carried out.

To summarize, we have seen here that the F1/F2 measurement results show that mid vowels in the penult undergo vowel harmony agreement for all three speaker groups; i.e. they are lower in the acoustic space when the following final syllable with the same vowel is CVC, an environment which triggers the lowering of the mid vowels. In addition, the low vowel /a/ is realized as [a] whether the following final syllable is CV or CVC. With respect to the high vowels, the F1/F2 results for the bilingual speakers from Central Java support the impressionistic observations, i.e. high vowels in the penult do not undergo vowel harmony. However, the results for the monolingual Indonesian speakers and the bilingual speakers from East Java show the opposite of what is expected. For the monolingual speakers, the high vowels lower when the following final syllable is CVC. For the Eastern Javanese speakers, while the front high vowel lowers in the acoustic space, the back one is similar preceding a final CV or CVC.

Other acoustic characteristics of these vowels may enhance their impressionistic quality. In the next section, I analyze the durations of the Indonesian vowels in the penult.

3.6.2 Vowel durations

If vowel duration correlates with vowel height, we would expect to see the tendency whereby higher vowels have shorter duration than lower vowels. In addition, if the syllable structure of the final syllable plays a role in the timing pattern of vowels in the penult, we may find the duration of vowels preceding an open final syllable to be greater than preceding a closed final syllable.

I compare first the penultimate vowels preceding an open final syllable and preceding a closed final syllable (i.e. iCV# vs. eCV#, etc. and iCVC# vs. eCVC#, etc.), then I compare the same vowel preceding a final syllable of different syllable structure (e.g. iCV# vs. iCVC#). In Figure 3.25, I present the duration mean values for the monolingual speakers.

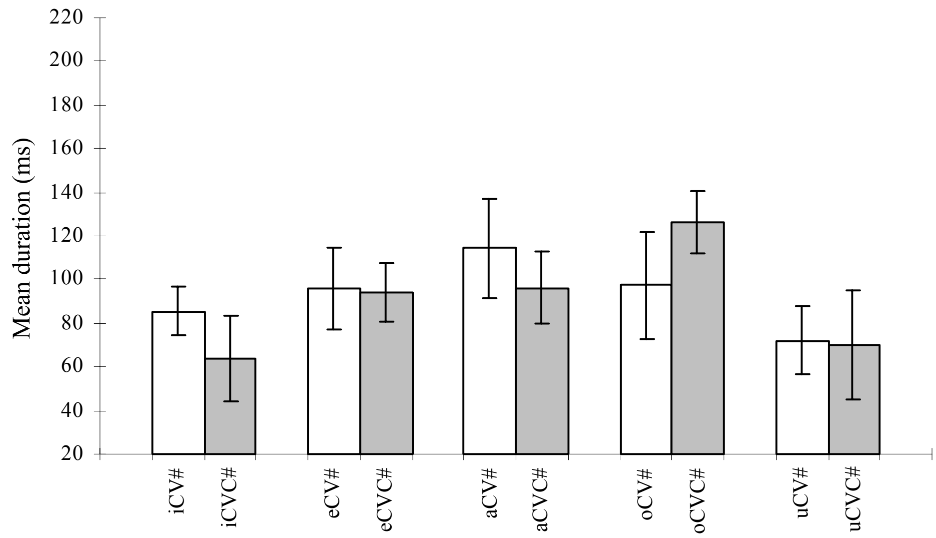


Figure 3.25: Mean durations (in ms) of Indonesian penultimate vowels preceding open vs. closed final syllables for the monolingual Indonesian speakers

In the open final syllable case, the mean duration values of the high vowels are lower than the values for the lower vowels. The low vowel /a/ has the greatest mean duration relative to the other higher vowels. In the closed final syllable case, the mean duration values of the high vowels are also lower than for the lower vowels. The mean values for /a/ and for /e/ are practically identical. The mean value for /o/ is relatively the greatest. The ranges of the mean differences are 1-42 ms in the open syllable cases and 2-62 ms in the closed syllable cases. Statistical analysis indicates that these differences are significant ($p < .05$) for /i/ vs. /a/, and for /e, a, o/ vs. /u/ in the open final syllable cases; in the closed final syllable cases, the differences among the vowels are significant, except for /i/ vs. /u/ and for /e/ vs. /a/. These results suggest that while the penultimate vowels preceding open final syllables show a systematic pattern, this is not the case for those preceding closed final syllables.

With respect to duration differences of vowels in the penult preceding open vs. closed final syllables, the mean values for /i/ and /a/ preceding the open final syllables are greater than preceding the closed final syllables. The mean differences are statistically significant ($p < .05$) for these two vowels. For /e/ and /u/, their mean values are similar. For /o/, the mean duration preceding the open final syllables is shorter than preceding the closed ones. The mean difference for /o/ is statistically significant.

I turn now to the duration of vowels in the penult for the bilingual speakers from Central Java. The measurement results are presented in Figure 3.26

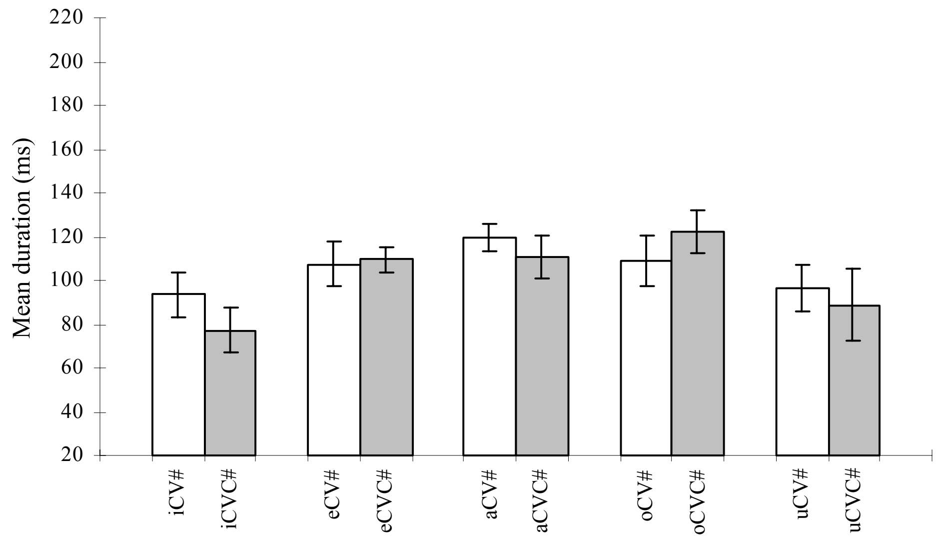


Figure 3.26: Mean durations (in ms) of Indonesian penultimate vowels preceding open vs. closed final syllables for the bilingual Central Javanese/ Indonesian speakers

Preceding open final syllables, the high vowels have lower mean values for duration as compared to the lower vowels. The low vowel /a/ is shown to have the greatest mean duration relative to the higher vowels. Preceding closed final syllables, high vowels also show to have lower mean values, while the mean values for /e/ and /a/ are practically identical. The mean value for the mid vowel /o/ is greater than for the low vowel /a/. The mean differences are statistically significant ($p < .05$) for the vowels in the open syllable cases, except for /i/ vs. /u/ and for /e/ vs. /o/. In the closed syllable cases, these differences are not statistically significant for /i/ vs. /u/ and for /e/ vs. /a/; they are marginally significant for /e/ vs. /o/ ($p = .04$). The results for the bilingual speakers from Central Java are very similar to the results for the monolingual speakers.

Comparing vowels preceding open vs. closed final syllables, the mean values of duration for /i/, /u/, and /a/ are greater in the open than in the closed final syllables. For the mid vowels, the mean values are lower in the open than in the closed final syllables, even though the difference for /e/ is quite small. Statistically, these differences are not significant for /i/, /a/, and /o/.

Next, I present the duration measurement of vowels in the penult for the bilingual speakers from East Java. The results are presented in Figure 3.27.

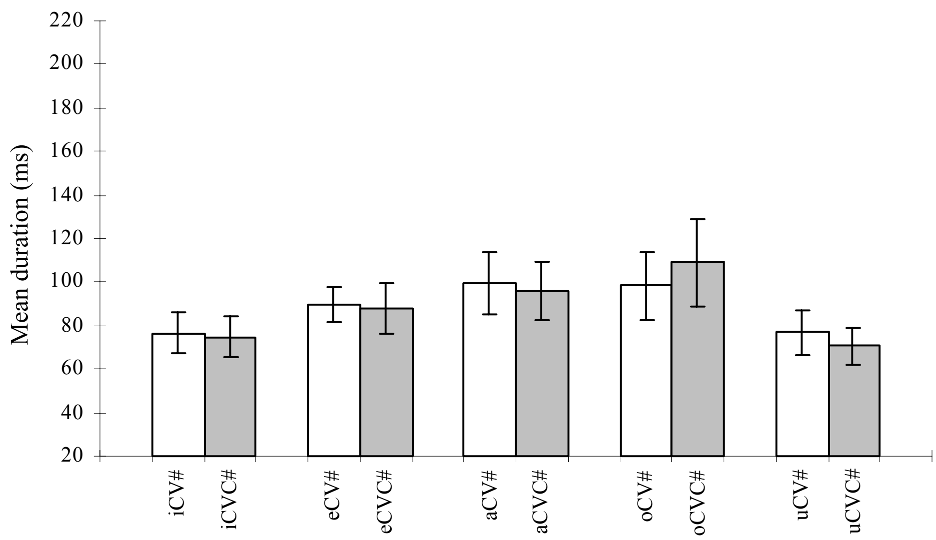


Figure 3.27: Mean durations (in ms) of Indonesian penultimate vowels preceding open vs. closed final syllables for the bilingual Eastern Javanese/ Indonesian speakers

Preceding open final syllables, the high vowels have the lowest mean durations. The durations of the mid vowel /o/ and the low vowel /a/ are practically identical. The duration for the mid vowel /e/ is between that for the high and the low vowels. Preceding closed final syllables, high vowels have the lowest mean durations, and the mid vowel /o/ has the greatest. The duration of the mid vowel /e/ is relatively greater than that of the high vowel /i/ but shorter than that of the low vowel /a/. Statistical analysis indicates that the mean differences for vowels preceding open final syllables are significant ($p < .05$) for /i, u/ vs. /a, o/; for vowels preceding closed final syllables, the differences are significant for /i/ vs. /a, o/, for /e/ vs. /o/, and for /u/ vs. /e, a, o/.

Comparing vowels preceding open vs. closed final syllables, the mean value differences are greater preceding open vs. closed final syllables for all vowels, except for /o/. These differences are small, and statistically not significant.

To summarize briefly the duration measurement results for all three speaker groups, preceding open final syllables, all vowels in the penult show the correlation between vowel timing pattern and vowel height. Preceding closed final syllables, the high vowels display the lowest mean durations as compared to lower vowels. The mean durations for /e/ and /a/ are similar, and the mean duration for /o/ is greatest as compared to the other vowels. As discussed earlier, the reason for /o/ to be 'deviant' may show the effect of the following root-medial rhotic in the word *sorot*.

In the next section, I present and discuss briefly the overall results of vowel formant structure and vowel duration for Indonesian.

3.6.3 Summary of results

In Table 3.7, I summarize the results of the acoustic measurements of Indonesian vowels in the penultimate position, as produced by the monolingual and the bilingual speakers, from both Central and East Java. Bold prints indicate differences among the speaker groups.

Table 3.7: Summary of the acoustic measurements of Indonesian vowels in the penultimate syllables

	Monolingual Indonesian	Bilingual Central Javanese	Bilingual Eastern Javanese
Formant structure	**1. Preceding CVC#, /i/ and mid vowels lower** 2. Vowel height: iCVC# ≠ eCV# uCVC ≠ oCV#	**1. Preceding CVC#, mid vowels lower** 2. Vowel height: iCVC# ≠ eCV# uCVC# ≠ oCV#	**1. Preceding CVC#, /i/ and mid vowels lower** 2. Vowel height: iCVC# ≠ eCV# uCVC# ≠ oCV#
Vowel duration	1. High vowels tend to be shorter than lower vowels when preceding CV# 2. Preceding CV# vs. CVC#: vowels preceding CV# may be greater, similar, or shorter than preceding CVC#	1. High vowels tend to be shorter than lower vowels when preceding CV# 2. Preceding CV# vs. CVC#: vowels preceding CV# may be greater, similar, or shorter than preceding CVC#	1. High vowels tend to be shorter than lower vowels when preceding CV# 2. Preceding CV# vs. CVC#: vowels preceding CV# may be greater, similar, or shorter than preceding CVC#

As discussed earlier, mid vowels in the penultimate position in Indonesian undergo vowel harmony. This phenomenon is observable when comparing the mid vowels in the penult preceding open vs. closed final syllables. We predict this to be the case for the monolingual Indonesian speakers; in addition, we predict that the influence of Javanese will manifest itself in the Indonesian of the bilingual speakers from Central and East Java.

The overall results of the acoustic measurements carried out here show that, for all the three speaker groups, the Indonesian mid vowels in the penult differ in quality preceding an open vs. closed final syllables, indicating that vowel harmony applies to the mid vowels in the Indonesian of the monolingual and the bilingual speakers. The results also indicate that, for the monolingual speakers and the bilingual speakers from East Java, front high vowel in the penult lowers when preceding a closed final syllable.

The results here also suggest that the difference of the Indonesian vowels in the penult is mainly due to their F1/F2 values. The results of the other acoustic measurements show no systematic pattern to indicate that they play a role in enhancing vowel quality distinction. This is consistent with the acoustic results for the Indonesian vowels in the final syllable.

3.7 Discussion

In this chapter, I have analyzed the Javanese and the Indonesian vowels, produced by speakers from different regions. The issues that are of interest concern vowel alternations governed by syllable structure in the penultimate and final positions. The location of vowels in the acoustic space is examined by analyzing the measurements of the first and second formant values. Other acoustic characteristics are also examined. The results indicate that the acoustic measurement of the first and second formant values is the most salient gauge for vowel quality distinction.

The F1/F2 measurements for the Javanese vowels show that high and mid vowels in final CVC syllables are lower in the acoustic space, as compared to their counterpart in final CV syllables. The high vowels in the CVC syllables lower to the extent that they are of similar height as the mid vowels in the CV syllables. In addition, /a/ in final CV syllables overlap with /o/ in final CVC syllables in the acoustic space. This is the case for the speakers from the Central and the Eastern regions. In the penultimate syllable, the acoustic realization of vowels is determined by the structure of the final syllables, indicating the effect of vowel harmony. For the Central Javanese, the mid and low vowels lower in the acoustic space when the final syllable is a CVC; for the Eastern Javanese, all vowels in the penult do when preceding a final CVC syllable.

The acoustic results for the Indonesian vowels indicate that high and mid vowels in final CVC syllables are lower in the acoustic space as compared to those in final CV syllables, for all three speaker groups. For the monolingual speakers, the lowered high vowels are still distinct from the non-lowered mid vowels. For the bilingual speakers, the lowered high vowels are either close to or share the same height as the non-lowered mid vowels. In the penultimate syllable, high and mid vowels lower preceding final CVC syllables, for the monolingual and the Eastern Javanese bilingual speakers. For the monolingual speakers, the lowered high vowels are distinct from the non-lowered mid vowels, similar to the case of high vowels in final CVC syllables. For the bilingual speakers, /i/ preceding a final CVC syllable lowers and almost overlaps with /e/ preceding a final CV syllable; however, /u/ preceding a final CVC syllable overlaps with its counterpart preceding a final CV syllable.

Several issues emerge, given the acoustic results here. The first issue concerns with the inconsistent high vowel lowering pattern shown by the bilingual speakers from Eastern Java. The second issue is with regards to the unexpected high vowel lowering in the Indonesian of the monolingual speakers. The third issue deals with identifying in which cases high vowel lowering is gradient vs. categorical. The fourth issue involves the perceptual nature of high vowels in Indonesian and Javanese.

We have seen earlier that Javanese high and mid vowels in the penultimate syllables are higher in the acoustic space when the final syllable is a CV and are lower when the final syllable is a CVC, for the Eastern Javanese speakers. This phenomenon is ascribed to vowel harmony. In the Indonesian of these speakers, however, the effect of vowel harmony is evident only for the front high vowel, but not for the back high vowel. (Vowel harmony also occurs in Indonesian, and it only applies to the mid vowels.) I hypothesize that this asymmetry is due to an extra-linguistic factor, namely the (psychological) effect of being recorded speaking Indonesian with a Javanese accent. This hypothesis is based on the observations that (1) some speakers indicated that the Indonesian spoken by those from Jakarta is the best representation of the language, and (2) some speakers appeared ill at ease to varying degrees during the recording. With respect to the production of Indonesian utterances, these speakers may have attempted to 'adjust' certain parts of the grammar (phonology in this case) in order to sound more 'standard' (or like those from Jakarta). We have also seen in the acoustic results that the vowel acoustic spaces of Javanese and Indonesian for the Eastern Javanese speakers are narrower than for the Central Javanese and monolingual Indonesian speakers, and vowel durations of Javanese and Indonesian for the Eastern Javanese speakers are relatively shorter than for the speakers from the other two groups, suggesting faster speech rate. This may, in turn, indicate the feeling of ill at ease during recording. Further study is needed where factors such as the degree of formality, the participants' identities, topic under discussion, etc., are carefully considered and better controlled for, to determine what factor/s influence the speakers' decision in modulating their accent, and which domains of the language are affected by this decision.

With respect to the high vowel lowering in the Indonesian of the monolingual speakers, there are two possible accounts. In the first account, one could argue that this lowering in the Indonesian of the monolingual speakers is phonological. If this is the case, Indonesian (at least of the monolingual speakers whose utterances are analyzed here) and Javanese would share a vowel pattern whereby high and mid vowels lower in final CVC syllables. The difference between the two languages in the acoustic realization of the lowered high vowels lies in the degree of lowering. For Indonesian, the lowered high vowels are considerably higher than the non-lowered mid vowels; for Javanese, there is a 'complete merge' between the lowered high vowels and the non lowered mid vowels (with respect to height for both front and back vowels, and backness as well for the front vowels). This different degree in lowering suggests that lowering in Indonesian is a phonetic phenomenon. If this is indeed the case, there are in fact two possible phonetic explanations for Indonesian: (1) the lowering indicates laxing, but it is not completely phonological, and (2) the lowering indicates an acoustic effect of the surrounding consonants. The acoustic results in this study seem to indicate that high vowel lowering in Indonesian is not related to consonantal context. This leaves us with the possibility for the Indonesian high vowels of undergoing laxing.

A related issue is the categorical vs. gradient nature of high vowel lowering in Javanese and Indonesian. As discussed previously in § 3.1, Javanese vowels are claimed to lower in final CVC syllables, with the underlying low vowel /a/ realized as [ɔ] in final CV syllables and as [a] in final CVC syllables. We have seen that the lowering of vowels governed by syllable structure in Javanese is acoustically realized in a systematic way, providing support for the view that this lowering is the acoustic realization of the phonological pattern of these vowels, thus categorical. For Indonesian, on the other hand, the issue of vowel lowering, especially with respect to the high vowels, is not straightforward. As discussed previously, there are two possible views. If this lowering is due to phonetic environment, then it is predicted to be gradient in nature. However, if it is part of the Indonesian phonology, then this lowering is categorical. The question, then, is whether it is possible to determine the nature of high vowel lowering in Indonesian, independent from the influence of the other language/s of its bilingual speakers. The contrast between the acoustic pattern of high vowels in the Indonesian of the bilingual Javanese speakers, on the one hand, and the pattern of these vowels in the Indonesian of the monolingual speakers and the bilingual Sundanese and Toba Batak speakers, on the other hand, suggests that high vowel lowering in Indonesian (proper) is a phonetic effect, and thus gradient. In the Indonesian of the bilingual speakers, and in the case where Indonesian bears the influence of another language, the high vowel lowering could be categorical, if it is part of the phonology of the other language. This is the case with the Indonesian of the Javanese speakers. A similar phenomenon whereby the issue of the categorical vs. gradient nature of vowel alternation is observed in vowel harmony vs. vowel raising in the Asante dialect of Akan, a West African language (Clements, 1985).

An interesting question that emerges from the fact that Indonesian can be metamorphic in a bilingual setting is how the allophones of the Indonesian vowels, especially the high and mid ones, produced by speakers from one language group are identified by speakers from another language group. Based on the informal interview with some of the speakers recorded in the present study, the bilingual speakers from Java identified high vowels in final CVC syllables in the Indonesian of **non-Javanese** speakers (in general), as sounding like [i] and [u]. This is consistent with the results in van Zanten's perception study (1989), in which the Indonesian high vowels in final CVC syllables, as produced by the bilingual Sundanese and the bilingual Toba Batak speakers, are identified as [i] and [u] by bilingual listeners from Malang (East Java). Looking at vowel perception from the reverse direction, van Zanten (1989) finds that Indonesian high vowels in final CVC syllables as produced by the bilingual Javanese speakers are identified as [e] and [o], respectively, by the Sundanese and Toba Batak listeners. No monolingual Indonesian speakers were involved in her perception study.

An interesting finding in van Zanten's perception study is the tendency for the **listeners from East Java** to misidentify /e/ and /o/ with

/i/ and /u/, respectively, in the final syllables of Indonesian CVCV and CVCVC words. The tokens, produced by Javanese, Sundanese, and Toba Batak bilingual speakers, include the same vowel in the penultimate syllable. Final consonants are deleted from the CVCVC words. The percentage of misidentification is higher for the front vowels (20-25%) than for the back ones (0-12%). This unexpected result, in fact, suggests the correlation between production and perception. The results in the present study show that penultimate high vowels, in the Javanese and in the Indonesian of the bilingual speakers from East Java, lower in the acoustic space when followed by high vowels in final CVC syllables, indicating the manifestation of high vowel harmony in the Eastern dialect of Java. The lowered high vowels are of similar height as the non-lowered mid vowels. The vowel harmony rule in Eastern Javanese affects the (mis)identification of non lowered /e/ and /o/, such that CeCe and CoCo tokens in van Zanten's study are perceived as C[ɪ]C[ɪ]C and C[ʊ]C[ʊ]C tokens, respectively.

In the next chapter, I compare the acoustic measurements of Javanese vs. Indonesian stops, the latter being produced by the monolingual and bilingual speakers. In Javanese, stops are either clear or breathy, while in Indonesian, they are either voiced or voiceless. The realization of the clear vs. breathy contrastive feature of stops in the Indonesian of the bilingual Indonesian/Javanese speakers is another case of the manifestation of Javanese phonological pattern in Indonesian.

CHAPTER FOUR:
BREATHY/CLEAR VS. VOICED/VOICELESS CONTRAST FOR THE BILINGUAL JAVANESE/INDONESIAN SPEAKERS

As mentioned in the introduction, Javanese stop series are distinguished as being breathy or clear, while Indonesian stops are either voiced or voiceless. Parallel to the discussion in Chapter 3, in cases involving bilingual speakers, the patterns in one language may be manifested in the other. For the bilingual Javanese/Indonesian speakers, the Indonesian stops may be realized with a voiced/voiceless distinction, if the Indonesian patterns prevail; but they may be realized with a breathy/clear contrast if the Javanese patterns are dominant. Hypothetically, it is also possible for Javanese stops to reflect the Indonesian patterns, but effects in this direction were not found. The focus in this chapter is first the acoustic realizations of the stop series in both Javanese and Indonesian. I then compare the bilingual Javanese/Indonesian speakers to the monolingual Indonesian speakers in their production of Indonesian stops.

The organization of the chapter is as follows. In § 4.1, I present the distribution of stops in Indonesian and Javanese. In § 4.2, I discuss phonetic studies on breathy vs. clear sounds. In § 4.3, I present previous acoustic studies on Indonesian and Javanese stops. The methods of abstracting values from the acoustic measurements of breathy vs. non-breathy sounds are discussed in § 4.4. The results of these measurements are presented in § 4.5 through § 4.7, followed by a brief discussion in § 4.8.

4.1 Stops in Indonesian and Javanese

As discussed briefly in Chapter 1, stops in Indonesian are distinguished as being voiced or voiceless and those in Javanese as breathy and clear. In this section, I discuss in further detail the occurrence of the stops in both languages, and how they are acoustically realized.

Indonesian has a series of supralaryngeal stops and affricates, and [ʔ], as shown in Table 4.1.

Table 4.1: Stops and affricates in Indonesian

	bilabial	coronal	palatal	velar	glottal
voiceless:	p	t̪	č	k	ʔ
voiced:	b	d	ǰ	g	

Note that palatals in Indonesian phonologically pattern with stops (as shown in (1)), though acoustically they are lightly affricated, a common phenomenon across languages (e.g. Lombardi, 1990).

The voiceless stops can occur in root-initial (shown in (1a)), root-medial (shown in (1b)), and root-final positions (shown in (1c)), but voiced stops are restricted to root-initial and root-medial positions (shown in (1a-b)). In addition, affricates are banned from occurring in root-final position (see Adisasmito-Smith, 1998 and the references therein).

(1) *Stops in Indonesian*

a. root-initial position

Voiceless stops		Voiced stops	
[*p*anah]	'arrow'	[*b*uka]	'open'
[*t*ali]	'rope'	[*d*asar]	'foundation'
[*č*uka]	'vinegar'	[*ǰ* uraŋ]	'ravine'
[*k*asar]	'rough'	[*g*aram]	'salt'

b. root-medial position

Voiceless stops		Voiced stops	
[ra*p*at]	'close'	[sa*b*ar]	'patient'
[ki*t*a]	'we'	[bi*d*aŋ]	'wide'
[kə*č*il]	'small'	[ba*ǰ*a]	'steel'
[su*k*a]	'like'	[la*g*u]	'song'

c. root-final position

Voiceless stops		Note:
[ata*p*]	'roof'	*[ata***b**]
[kila*t*]	'lightning'	*[kila***d**]
[masu*k*]	'enter'	*[masu***g**]

As suggested in (1c), no form ends with a voiced stop. Note, however, that orthographically, there are borrowed lexical items with a voiced stop in word-final or syllable-final position, such as *ahad* 'Sunday', *abad* 'century', *sabtu* 'Saturday'. These words are of Arabic origin, and impressionistically are pronounced with a voiceless stop: [ahat], [abat], and [saptu].

A homorganic nasal may immediately precede a root-medial stop in Indonesian. This is the case for both voiced and voiceless stops, as shown in (2). For detailed discussion of the syllabification status of nasal + stop sequences in Indonesian, see Chapter 5.

(2) *Root-medial nasal + stop clusters in Indonesian*

Nasal + voiceless stop		Nasal + voiced stop	
[ta*mp*ak]	'appear'	[ta*mb*ak]	'pond'
[mi*nt*a]	'ask for'	[pi*nd*ah]	'move'
[pi*ɲč*aŋ]	'limp'	[ma*ɲǰ*a]	'spoiled'
[ba*ŋk*it]	'raise'	[ba*ŋg*a]	'proud'

Homorganic nasals in NC clusters do not occur in root-initial or root-final positions. Root-initially, however, a stop may immediately follow a prefixal nasal that surfaces as homorganic, such as the verbal prefix *məN-*. Thus, nasal + voiced stop sequences also occur across prefix-root boundary (as shown in (3a)), but not nasal + voiceless stop clusters. These undergo coalescence, except for the voiceless affricate (as shown in (3b)).

(3) *Nasal + stop clusters in prefix + root boundary in Indonesian*

a. Nasal + voiceless stops

/məN/ + /putar/	→ [məmutar]	'turn'
/məN/ + /tari/	→ [mənari]	'dance'
/məN/ + /čuri/	→ [məɲčuri]	'steal'
/məN/ + /kutuk/	→ [məŋutuk]	'curse'

b. Nasal + voiced stops

/məN/ + /buka/	→ [məmbuka]	'open'
/məN/ + /didik/	→ [məndidik]	'educate'
/məN/ + /ǰala/	→ [məɲǰala]	'catch in a net'
/məN/ + /gigit/	→ [məŋgigit]	'bite'

In root-final position, all nasals are specified for place of articulation and do not assimilate to the place of articulation of a following stop. A suffix-initial stop may immediately follow a root-final nasal. Illustrated in the set of examples in (4) is the case where a root-final nasal is adjacent to a stop-initial benefactive suffix *-kan*. The prefix *məN-* forms a verb.

(4) *Nasal + stop sequences in root-suffix boundary in Indonesian*

/məN/ + /salin/ + /kan/	→ [məɲali***nk***an]	'copy'
/məN/ + /main/ + /kan/	→ [məmai***nk***an]	'play'
/məN/ + /gəŋgam/ + /kan/	→ [məŋgəŋga***mk***an]	'hold in fist'
/məN/ + /hitam/+ /kan/	→ [məŋhita***mk***an]	'blacken'

In this chapter, we focus on the acoustic properties of Indonesian stops in root-medial position, intervocalically and in a NC cluster. I turn now to the discussion of stops in Javanese. They occur at five places of articulation: labial, dental, alveolar or retroflex, palatal, and velar. Similar to the case in Indonesian, the palatals are phonologically stops and they are slightly affricated. One of the major differences between Indonesian and Javanese stops is that in Javanese, stops are breathy or clear, rather than voiced or voiceless. Both breathy and clear stops may occur in root-initial (shown in (5a)), root-medial (shown in (5b)), and root-final (shown in (5c)) positions. The glottal stop can only occur in the root-final position in the native vocabulary, as shown in (5c).

(5) *Stops in Javanese*

a. root-initial position

breathy stops		clear stops	
[p^{ɦ}awaŋ]	‘onion’	[pawaŋ]	‘animal caretaker’
[t^{ɦ}ɔwɔ]	‘long’	[tɔwɔ]	‘bargain’
[ʈ^{ɦ}uku]	‘k.o. fruit’	[ʈukʊl]	‘grow’
[č^{ɦ}uŋkat]	‘comb’	[čuŋkɪl]	‘uproot’
[k^{ɦ}ulɔ]	‘sugar’	[kulɔ]	‘1st person sg. ’

b. root-medial position

Breathy stops		clear stops	
[kap^{ɦ}ʊr]	‘run away’	[kapur]	‘chalk’
[sɔt^{ɦ}ɔ]	‘stick’	[mɔtɔ]	‘eye’
[pɔʈ^{ɦ}ɔ]	‘same’	[baʈʊʔ]	‘forehead’
[lək^{ɦ}i]	‘sweet’	[sukət]	‘grass’

c. root-final position

clear stops		breathy stops	
[it^{ɦ}əp]	‘eyelashes’	[k^{ɦ}ujʊp$^{(ɦ)}$]	‘friendly, close’
[liwat]	‘pass’	[lɔlɔt$^{(ɦ)}$]	‘choke’
[k^{ɦ}əʈ^{ɦ}ɛk]	‘bamboo wall’	[k^{ɦ}ut^{ɦ}ɪk$^{(ɦ)}$]	‘skin disease’
[səŋaʔ]	‘sharp smell’		

As shown in (5c), the root-final breathy stops are impressionistically realized as clear stops when they are word-finally.

When a vowel-initial suffix follows these roots, the stops are impressionistically breathy (the parentheses around the breathy release are to indicate that these stops are phonologically breathy); e.g. /pa + kʱujupʱ + an/ → [pakʱujupʱan] ‘traditional organization’, /kə + lɔlɔtʱ + ən/ → [kᵊlɔlɔtʱən] ‘accidentally choke on something’, /kʱutʱikʱ + ən/ → [kʱutʱikʱən] ‘suffer from skin disease’.

A limited set of consonant clusters may occur in Javanese, such as a stop preceded by a homorganic nasal. These occur in root-initial and root-medial positions. In root-initial position, a nasal and a stop can be adjacent when a prefixal nasal that surfaces as homorganic occurs with a root that begins with a stop. The examples shown in (6) illustrate the occurrence of an adjacent nasal with breathy and clear stops at all five places of articulation. As in Indonesian, coalescence occurs to the adjacent prefixal homorganic nasal and root-initial clear stop. The prefix /*N*-/ forms a verb.

(6) *NC clusters in prefix + root boundary in Javanese*

a. breathy stops

N- + /pʱakar/	→ [mbʱakar]	‘burn’
N- + /tʱulaŋ/	→ [ndʱulaŋ]	‘feed’
N- + /ʈʱaŋaʔ/	→ [nɖʱaŋaʔ]	‘look up’
N- + /čʱaluʔ/	→ [ɲǰʱalʊʔ]	‘ask for’
N- + /kʱuju/	→ [ŋgʱuju]	‘laugh’

b. clear stops

N- + /paku/	→ [maku]	‘nail’
N- + /tuluŋ/	→ [nulʊŋ]	‘help
N- + /ʈuʈuʔ/	→ [nuʈʊʔ]	‘hit’
N- + /čɔlɔŋ/	→ [ɲɔlɔŋ]	‘steal’
N- + /kukus/	→ [ŋukʊs]	‘steam’

Note that the acoustic realization of breathy stops following a homorganic nasal is voiced, in that a voice bar, indicating that the vocal cords vibrate, is present during the closure of the stop (Adisasmito-Smith, 1999a). This will be further discussed in § 5.3.

A homorganic nasal can also occur adjacent to a stop in root-medial position, as shown in (7). In contrast to the cases presented in (6), in medial position, no coalescence takes place when a homorganic nasal occurs adjacent to a clear stop.

(7) *NC clusters in root-medial position in Javanese*

breathy stops		clear stops	
[tɔmbʱɔ]	‘cure’	[tɔmpɔ]	‘receive’
[lindʱu]	‘earthquake’	[pintu]	‘door’
[bɔnɖʱɔ]	‘wealth’	[munʈu]	‘mortar’
[bənǰʱʊt]	‘bump on head’	[panči]	‘cooking pot’
[liŋgʱɪs]	‘machete’	[siŋkɪr]	‘put aside’

In root-final position, a nasal may become adjacent to a stop when it is followed by a suffix that begins with a stop. No place assimilation or coalescence takes place. In the set of examples shown in (8), the root is followed by the benefactive suffix *-ke*.

(8) *NC clusters in root-final position in Javanese*

N- + /kurpʱan/ + /ke/	→ [ŋʊrpʱa*nk*e]	'sacrifice'
N- + /simpən/ + /ke/	→ [ŋimpə*nk*e]	'keep'
N- + /tanəm/ + /ke/	→ [nanə*mk*e]	'plant'
N- + /antəm/ + /ke/	→ [ŋantə*mk*e]	'hit'

In the next section, I discuss the nature of breathy sounds, how they are produced, what their acoustic characteristics are, and how relative breathiness is quantified. Recall that in this study, the stops in Javanese that are contrastive along the breathy/clear line are compared with the stops in Indonesian that are distinguished as voiced or voiceless. Quantifying the acoustic characteristics of these two sets of stops would show us the ways in which they are different or similar.

4.2 Breathy voice quality

There have been a number of studies on the production of sounds that are characterized as breathy. Breathy voice quality may occur in both disordered and normal speech productions. In normal speech, breathy voice quality is considered as a modification of modal voice (Laver, 1980). In its production, it is characterized as a case where the vocal folds have an inefficient mode of vibration, since they vibrate loosely along their whole length. Consequently, there is a higher rate of airflow through the glottis that results in slight audible friction (e.g. Laver, 1980; Ladefoged et al., 1988). Perceptually, breathy voice quality is described as a sound with a muffled quality. Due to the higher rate of airflow, it has also been described as whispery. Laver argues that while breathy and whispery sounds are close from the auditory point of view, they are produced in the opposite manner with respect to the degree of tension of the vocal folds. In disordered speech, breathiness is caused by pathological conditions that affect the mechanism of the larynx (e.g. Hillenbrand et al., 1994). Physiological changes due to aging have also been found to cause the development of breathiness in male speakers (e.g. Linville 2001). Of interest here is breathy voice as part of normal speech.

Breathy voice quality plays a range of roles, from linguistic to paralinguistic. In some languages around the world, this voice quality is part of the phonemic system, e.g. Hindi (Ohala, 1979; Schiefer, 1986), Jalapa Mazatec (Kirk et al., 1984; Ladefoged et al., 1988; Silverman et al., 1995), !Xóõ (Bickley, 1982; Ladefoged, 1983), among others. Non-contrastive breathiness of vowels may also result due to laryngeal coarticulation, such as following an intervocalic /h/ in English *behind* and *ahead* (Ladefoged, 1983, 2001;) and in Tagalog *mahal* 'expensive' (Blankenship, 1997). See also Löfqvist and McGowan (1992) and Miller-Ockhuizen (forthcoming), among others, for cases of non-contrastive breathiness due to laryngeal coarticulation.

Some studies on English speakers have also found that female speakers tend to be breathier than male ones (Hanson, 1997). This tendency may serve as a social marker (e.g. Henton and Bladon, 1985; MacKay, 1987; Klatt and Klatt, 1990) or be due to physiological differences (e.g. Henton, 1987; Linville, 2001). The focus in the present study is the acoustic realizations of Javanese stops that are contrastive in breathy vs. clear voice qualities, and the acoustic comparison of Javanese stops with the Indonesian ones that are distinguished as voiced vs. voiceless. Therefore, it is the phonemic use of breathy sounds that is of concern here.

As part of the phonemic system of a language, breathy voice sounds are in contrast with non-breathy ones to distinguish the meaning of words in minimal pair. There are several terms used to refer to this voice quality contrast such as murmur vs. modal voice (e.g. Ladefoged, 1973), lax or slack vs. modal (e.g. Maddieson and Ladefoged, 1985; Henton et al., 1992), heavy vs. light (e.g. Fagan, 1988), breathy vs. modal (e.g. Klatt and Klatt, 1990), or vs. clear (e.g. Fischer-Jørgensen, 1967). In languages with a breathy contrast, either the vowels or the consonants may bear the contrast (Ladefoged, 1983). In languages like Hindi, the contrast of breathiness occurs among the voiced stop series (which is parallel to the aspiration contrast in the voiceless stops (Davis, 1994)), while in languages like Khmer among the voiceless ones.

In terms of their articulation, one of the main differences between modal and breathy voice is the state of the glottis (i.e. the space between the vocal cords), namely the degree of glottal adduction (or closure). In the production of voiced modal sounds, the vocal cords are close to each other along their length and they vibrate; the glottis is defined as adducted. This configuration is schematized in Figure 4.1a.

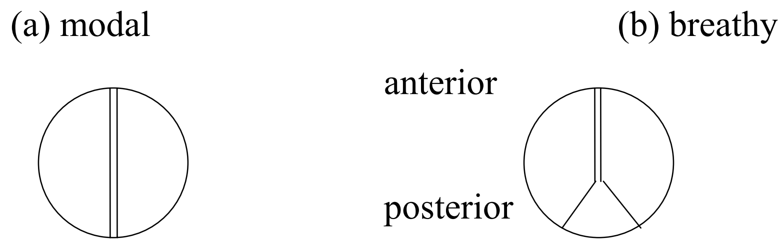


Figure 4.1: Diagram of the vocal cord setting during the production of modal and breathy voice quality

In the literature on breathy voice, there are at least two types of glottal configurations in the production of a breathy sound. One configuration is where the vocal cords are apart along their sides, as in the production of voiceless sounds. Due to the rapid flow of air, the vocal cords vibrate loosely. This configuration is described to be the case for an intervocalic [h] in English *behind* and *ahead* (Ladefoged, 2001). Another configuration is where the anterior part of the vocal cords maintains the configuration of the non-breathy setting where both vocal cords are close to each other along their side. However, the posterior part of the vocal cords is apart due to the pull of the arytenoid cartilages, also referred to as *glottal chink*. This is schematized in Figure 4.1b.

In the production of breathy sounds, the glottis is more abducted as there is a greater opening of the glottis for a breathy sound than for the modal one. The different degree of glottal abduction can be observed from the acoustic quality of modal and breathy voices. One of the acoustic correlates distinguishing modal vs. breathy sounds that is found in different languages is fundamental frequency (F0), in that breathy sounds tend to have lower F0 than their modal counterparts (e.g. in Gujarati (Fischer-Jørgensen, 1967), in !Xóõ (Ladefoged, 1983), in Hindi

(Ohala, 1979), in Ju|'hoansi (Miller-Ockhuizen, forthcoming), etc.). Note, however, that voiced obstruents, during which closure the vocal folds vibrate against each other, also has the effect of lowering vowel F0, as compared to voiceless obstruents. The differences between modal and breathy voices with respect to the vocal folds may be viewed "… as forming a continuum, ranging from open through successively narrower adjustments, producing breathy voice, slack voice,[9] modal voice, stiff voice, creaky voice and glottal closure" (Henton et al., 1992). Thus, excluding other acoustic characteristic differences between breathy voice and modal voice, these two voice qualities would not be distinguishable with respect to F0 lowering.

Henton et al. define breathiness in terms of vocal fold contact, position of arytenoids cartilages, and rate of airflow. A breathy vowel would have much less vocal fold contact, arytenoids cartilages that are further apart, and higher rate of airflow, as compared to a modal vowel. These differences result in acoustic dissimilarities, such as weaker spectral energy at high frequencies (above 2000 Hz) and strong low-frequency energy (Stevens, 2000). The manifestation that correlates with this acoustic characteristic is difference in spectral tilt between breathy vs. modal vowels, which has been widely reported based on a wide range of languages as well as in the studies of breathiness in female speakers. The

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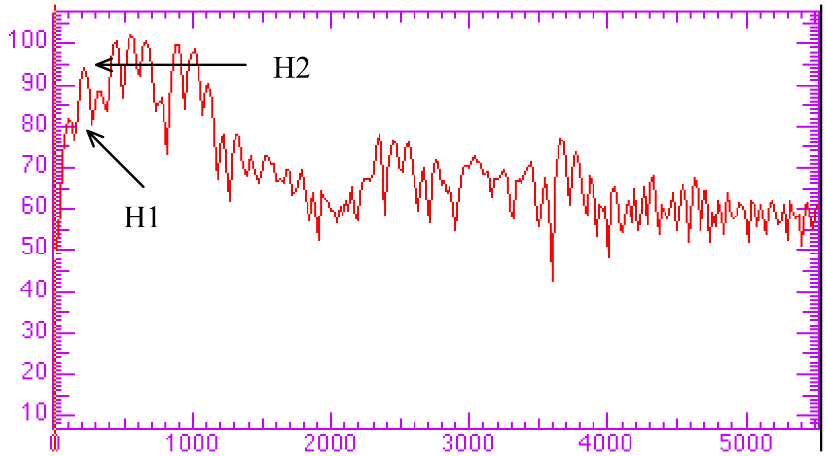
[9] Henton et al. (1992) characterize Javanese stops as being slack rather than breathy, based on the fact that they are voiceless with a breathy release. This implies that the vowels following these stops, [$p^{ɦ}$, $t^{ɦ}$, $k^{ɦ}$], would have "… a slightly increased glottal aperture beyond that for modal voice…" and "… a moderate increase in flow", as slack stops would. However, no quantified data on Javanese stops are available to distinguish their being more slack or more breathy, and speakers may vary with respect to the degree of glottal aperture and the rate of airflow. Thus, at this point, I will keep the characterization of Javanese stops as breathy vs. clear. Future articulatory and aerodynamic research may help determine whether Javanese non-modal stops tend to be more breathy or slack.

degree of tilt is measured by comparing the difference between the amplitude of first harmonic (the fundamental frequency) and that of higher ones (e.g. Bickley1982; Henton and Bladon, 1985; Ladefoged and Antoñanzas-Barroso, 1985; Jackson et al., 1985a, 1985b; Hillenbrand et al., 1994; Hanson, 1997, among others). The differences in spectral tilt for modal vs. breathy voice are argued to result from the different degree of glottal adduction. As mentioned earlier, the vocal cords are relatively more adducted for modal voice than for breathy voice. The greater degree of adduction leads the vocal cords to vibrate rapidly and in such a way that there is an abrupt discontinuity of the airflow. This, in turn, results in a relatively high degree of acoustic energy in the harmonics in the higher frequencies. For breathy voice, on the other hand, the more lax vibrations of the vocal cords result in relatively less acoustic energy in the harmonics in the higher frequencies and more energy at the fundamental frequency (e.g. Jackson et al., 1985; Ladefoged and Antoñanzas-Barroso, 1985; Hanson, 1995, 1997; Stevens, 2000). To quantify the degree of spectral tilt, the amplitude of the fundamental frequency is compared with that of the higher ones, such as the second harmonic and the third formant (F3) peak. The differences in spectral tilt between modal and breathy vowels are illustrated in Figures 4.2 and 4.3.

(a) raka ‘brother’ at 30% point



(b) rak^{ɦ}a ‘body’ at 30% point

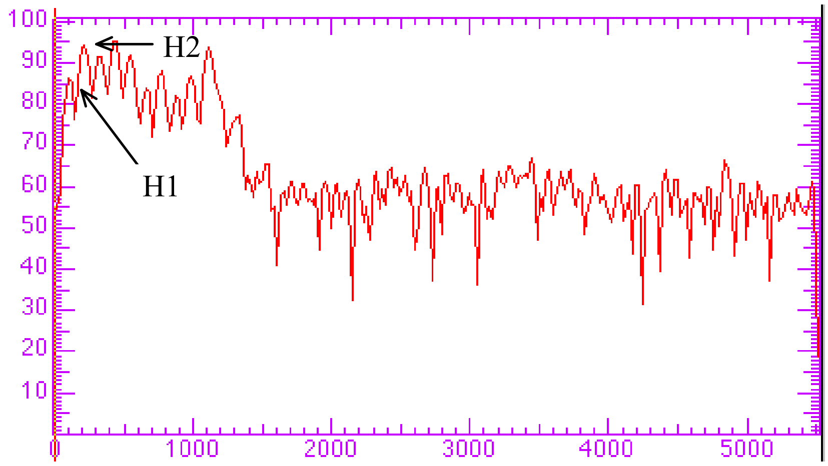


Figure 4.2: Differences of the amplitude of the first harmonic (H1) and that of the second harmonic (H2) for (a) a clear (or modal) vowel vs. (b) a breathy vowel in Javanese (Speaker CJ_m7)

In Figure 4.2, each peak in the FFT spectrum indicates the amplitude of individual harmonics. The first two peaks on the left of both displays are the first and second harmonics. As shown here, the difference between the energy peaks of these two harmonics is relatively smaller for the modal voice than for the breathy voice. The differences here are due to the higher energy of the first harmonic for the breathy vowel (86 dB), as compared to that for the modal vowel (82 dB).

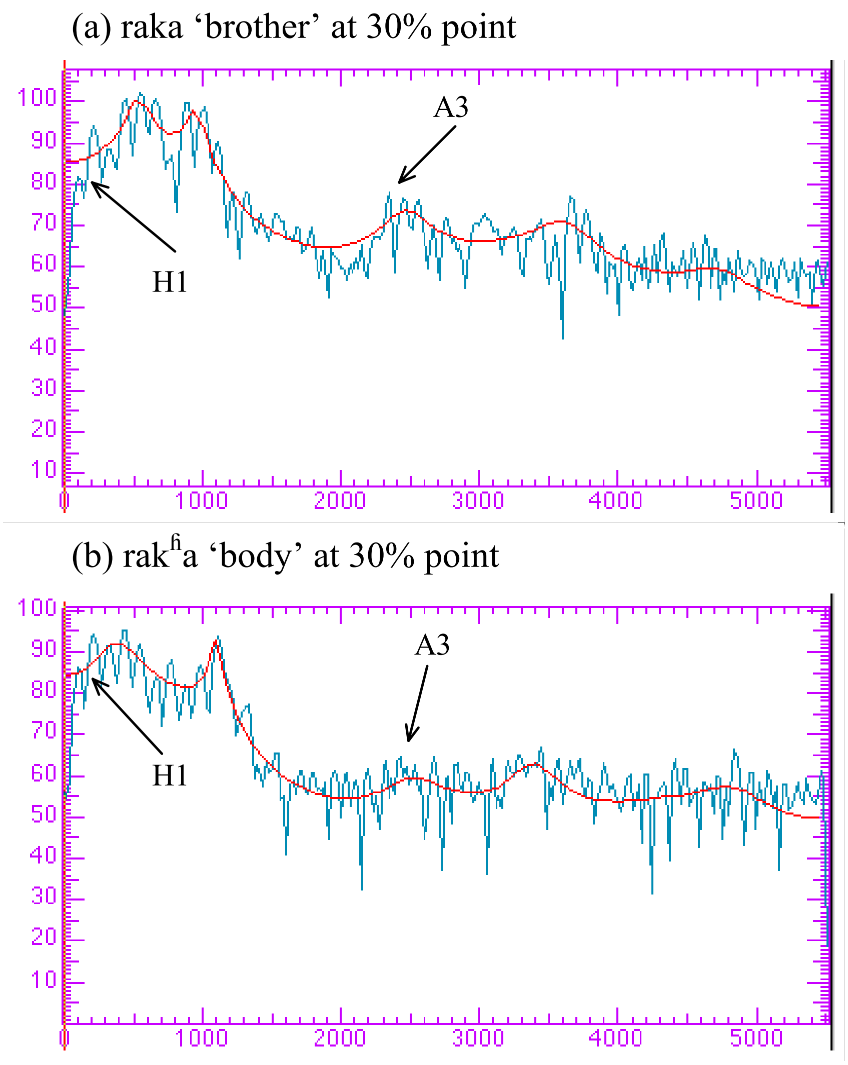
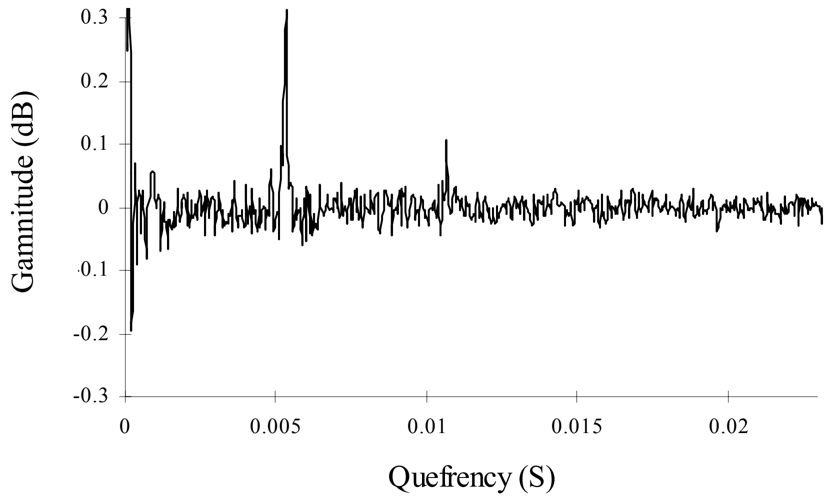


Figure 4.3: Differences of the amplitude of the first harmonic (H1) and that of the third formant (A3) for (a) a clear (or modal) vowel vs. (b) a breathy vowel in Javanese (Speaker CJ_m7)

In Figure 4.3, I show the differences in amplitude, in two FFT spectra, for the first harmonic (H1) and the third formant (A3). While the energy of the first harmonic is greater for breathy voice than for modal voice, there is a decrease of energy for the F3 peak of breathy voice (79 dB) as compared to the energy for the F3 peak of modal voice (63 dB).

The different glottal configurations for modal vs. breathy voices also lead to differences in the volume of airflow. The greater degree of glottal opening during breathy phonation results in a higher degree of airflow, which in turn, results in a higher degree of noise. Comparing the degree of noise in the F3 region (2300-2950 Hz), Klatt and Klatt (1990) finds that there is a greater degree of noise for female speakers than for male speakers (and female speakers have been found to exhibit the tendency of being breathier than male speakers). To quantify sound signals with differing degree of noise, de Krom (1993) proposes a cepstral measure that separates the harmonics from the noise. He finds this algorithm to successfully distinguish synthetic vowels with differing levels of noise bursts at the frequency range of 60-2000 Hz. The result of applying the cepstral measure would show cepstral amplitude (i.e. gamnitude) for vowels following a modal (or clear) stop to be greater than following a breathy stop. A similar cepstral measure, Cepstral Peak Prominence, is proposed by Hillenbrand et al. (1994); in this measure, a more prominent cepstral peak is indicative of a well defined harmonic structure, which, in turn, suggests a highly periodic signal. The cepstra presented in Figure 4.4 illustrate the result of applying de Krom's cepstral measure on vowels following modal vs. breathy consonants in Javanese, at the frequency range of 3000-4000 Hz. The measurement was taken at the mid point of the vowel.

(a) raka



(b) rak^{ɦ}a

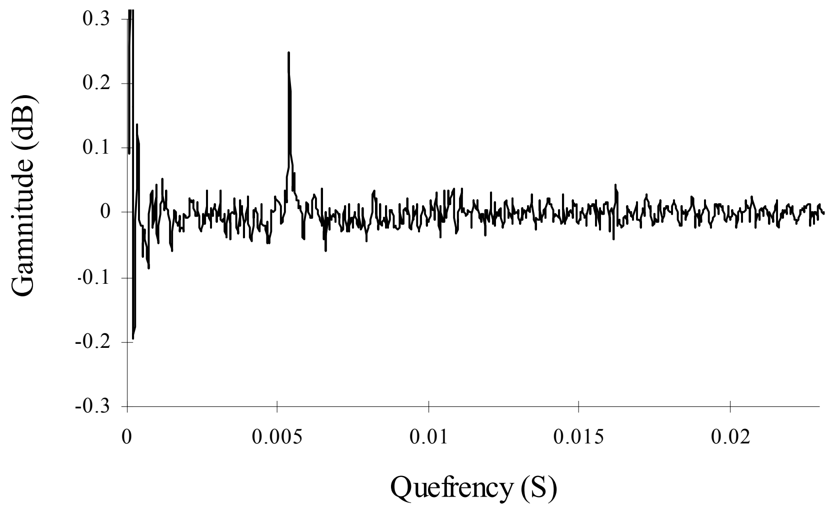


Figure 4.4: Cepstra of Javanese vowels following root-medial (a) modal vs. (b) breathy velar stops, produced by Speaker CJ_m7

As shown here, the cepstral amplitude is greater for the vowel following /k/ than for the vowel following /k^{ɦ}/. This cepstral measure is in turn used to calculate the harmonics-to-noise ratio (HNR). This algorithm has been found to be reliable to distinguish modal vs. breathy vowels in Javanese (Wayland et al., 1994) and Ju|'hoansi (Miller-Ockhuizen, forthcoming).

The incomplete closure of the glottis during breathy phonation, resulting in higher degree of airflow, also results in faster loss of energy in the glottal area. This loss of energy has been argued to affect the first formant bandwidth (B1) (e.g. House and Stevens, 1956; Fujimura and Lindqvist, 1971; Hanson, 1997), in that the greater the energy loss, the greater the vowel B1 is. In these studies, especially in Fujimura and Lindqvist's and in Hanson's, B1 measurements are based on the speech of male vs. female speakers. Wider B1 is found for the female speakers. Wider B1 is also associated with a dampened first formant. Based on this, Hanson (1997) proposes a method to quantify B1 by measuring the difference between the amplitude of the first harmonic and that of the first formant (A1). I adopt Hanson's measure of H1-A1 as a measure of vowel B1 in this dissertation.

In the next section, I discuss the acoustic findings of Javanese stops in previous studies. The findings in these studies show which acoustic measures correlate with breathy stops in Javanese.

4.3 Acoustic studies of breathy voice in Javanese

Impressionistic observations regarding the breathiness of Javanese stops have been made in several works (e.g. Uhlenbeck, 1978; Horne, 1974; Ladefoged, 1971; Poedjosoedarmo, 1988, to name a few). However, there are only a few instrumental studies that have been carried out.

The earliest acoustic study that I am aware of was carried out by Fagan (1988). In his study, Fagan quantifies several acoustic characteristics of Javanese stops. His findings show that the durations of the breathy vs. clear stop closure are very similar, and the voice onset time (VOT) values do not show a consistent pattern. VOT values have been found to distinguish voiced vs. voiceless stops in many languages, in that voiceless stops tend to have greater VOT values than voiced stops (e.g. Lisker and Abramson, 1964). The results found by Fagan support the suggestion that the Javanese stops may be phonemically distinguished as breathy vs. clear, and that the phonation type difference of these stops is not realized acoustically in the stops themselves. Rather, the stop contrast is acoustically realized in the following vowel. A similar case has been found in Wu dialects and Xhosa, whereby the phonation type contrast of consonants (stops and clicks) is acoustically realized in the following vowel, rather than in the consonants themselves (Cao and Maddieson, 1992; Jessen and Roux, 2002).

By systematically comparing the acoustic differences of vowels following breathy vs. clear stops, Fagan finds that the first formant frequencies of the following vowel, at the onset and at the steady state points, is consistently shown to be lower after a breathy stop; the vowel second formant is found to be higher, especially at the onset point. He suggests that for the first formant, the differences for vowels following the different phonation types are due to the different height of the larynx. The lowering of F1 following a breathy stop results from larynx lowering. While no explanation was offered as to why the second formant is higher after a breathy stop, as this is contrary to the expected results if the larynx indeed lowers, the results are shown to be quite consistent. It is possible that the increase of the second formant frequency results from the greater rate of energy loss for vowels following a breathy stop, due to the glottal configuration, namely the incomplete glottal closure (Fujimura and Lindqvist, 1971).

Fagan also finds that the F0 of vowels following breathy stops tends to be lower than those following clear ones, consistent with findings in other languages, e.g. Gujarati (Fischer-Jørgensen, 1967), !Xóõ (Ladefoged, 1983), Hindi (Ohala, 1979), Ju|'hoansi (Miller-Ockhuizen forthcoming), etc. and in subsequent acoustic studies on Javanese (Hayward, 1993; Wayland et al., 1994). However, this is not necessarily the case for all speakers. In a preliminary acoustic study (Adisasmito-Smith, 1999a), I find this to be the case for only one out of four Javanese speakers. Watkins (1998, 2002) also finds that only some speakers of Wa (nine out of eleven) show the pattern where F0 is lower for breathy vowels. In the studies of Adisasmito-Smith's and Watkins', the results also show that the combination of acoustic correlates realized by speakers may be different. This suggests that speakers may not produce breathy sounds in exactly the same way, such that the acoustic effects of these sounds manifest differently for different speakers.

Variability is, in fact, found by Hayward (1995). She reports on the results of an articulatory study of Javanese breathy vs. clear stops using fibreoptic laryngoscopy, of one male and one female speakers. For both speakers, there is an opening along and at the anterior end of the vocal folds. However, for the male speaker, the arytenoid cartilages remain close together, and for the clear stops, the vocal folds appear slightly bowed. For the female speaker, there is an opening at the posterior section, similar to the configuration schematized in Figure 4.1b. Hayward suggests that the opening for the female speaker may account for the aperiodic energy at high frequencies, consistent with the claim in other studies, e.g. Klatt and Klatt (1990), de Krom (1993). Based on the results of F0 measurements, she also suggests that the glottal configuration for the female speaker may have greater effect on F0 for breathy vs. clear phonation, as compared with the glottal configuration and its effect on F0 for the male speaker.

With respect to vowel duration, Fagan finds that vowels preceding Javanese stops do not show a relation with the clear/breathy distinction. Nor does the duration of vowels following these consonants. This is contrary to the findings by Wayland et al. (1994) who show that Javanese vowels following breathy stops are greater in duration as compared to vowels following clear stops. Wayland (1997) also finds this to be the case for breathy vs. clear vowels in Chantaburi Khmer.

Wayland et al. also find vowel intensity to be a reliable parameter to quantify relative breathiness in Javanese, with the intensity being higher for vowels following breathy than for those following clear stops. However, in a previous acoustic study (Adisasmito-Smith, 1999a), I find that vowel intensity is not always higher for vowels following breathy stops than for those following clear stops.

As previously discussed, spectral tilt is an acoustic effect that has been found to correlate with relative breathiness. Comparing the amplitude values of the first and second harmonics (H1-H2), Hayward (1993, 1995) finds that the H1-H2 values are greater for breathy vowels than for non-breathy ones; i.e. the downward tilt of H1 and H2 is steeper for breathy vowels than for their non-breathy counterparts. (See Figure 4.2 for illustration.) This concurs with findings in other languages such as Gujarati (Fischer-Jørgensen, 1967), Hmong (Huffman, 1987), Ju|'hoansi (Miller-Ockhuizen, forthcoming), Wa (Watkins, 1998, 2002), !Xóõ (Ladefoged et al., 1988). Hayward also finds that the H1-H2 value for vowels following breathy NC cluster is almost as low (i.e. small degree of tilt) as for vowels following an intervocalic clear stop, suggesting that the breathy stops in NC clusters are less breathy than the intervocalic breathy stops. In Adisasmito-Smith (1999a), I find that only two out of four speakers show the pattern where the H1-H2 values are greater for vowels following the intervocalic breathy stops than for vowels following the clear stops. One of the speakers in that study shows a pattern similar to that in Hayward's study, in that the H1-H2 values for vowels following breathy NC clusters are only slightly smaller as compared to the values for vowels following clear NC clusters.

In addition to comparing the amplitude values of the first two harmonics for breathy vs. clear vowels, spectral tilt can also be measured by comparing the amplitude values of the first harmonic and that of vowel F3 peak, H1-A3 (e.g. Hanson, 1997). In my preliminary study of Javanese breathy stops (Adisasmito-Smith, 1999a), I find that three out of four speakers show a consistent pattern with respect to H1-A3, in that the downward tilt is steeper for vowels following the breathy stops than for those following the clear ones.

In the 1999 study, I also quantify the first formant bandwidth (B1) using the method proposed by Hanson (1997), i.e. H1-A1. I find that the

B1 for vowels following breathy stops tends to be wider than for those following their clear counterparts, in both the intervocalic and NC cluster cases, for all speakers. This finding suggests that Hanson's method, which is applied to vowel B1 of female speakers of American English where breathiness is not phonemic, is also suitable to measure vowel B1 of speakers of a language where breathiness is phonemic.

As mentioned earlier, the incomplete glottal closure during breathy phonation results in the increase of additive noise at high frequencies (e.g. between 2300-2950 Hz in Klatt and Klatt's study (1990)). An acoustic measure that has been found reliable to quantify harmonic energy is harmonics-to-noise ratio (HNR), proposed by de Krom (1993). Adopting this algorithm, Wayland et al. (1994) find that the HNR values in the frequency regions of 2-5 kHz are higher for Javanese vowels following clear stops than following breathy ones. Looking at these same frequency regions and using the HNR algorithm proposed by de Krom, I find that only one out of four speakers shows the expected pattern for vowels following the intervocalic stops (Adisasmito-Smith, 1999a). Similarly, Wayland (1997) finds that speakers of Chantaburi Khmer do not uniformly display lower HNR values for breathy vowels. These suggest that the glottal configuration that produces breathy sounds may not always result in a considerable increase in airflow, which is acoustically manifested as an increase of noise in the high frequency regions, and that speakers may emphasize other strategies to produce the breathiness effect. However, it is also possible that the higher airflow in breathy sounds is realized in the range of frequencies beyond 5000 Hz. Miller-Ockhuizen (forthcoming) finds an increase in noise, using frequency range of up to 11,025 Hz.

To date, there is no published aerodynamic data on Javanese stops. Ladefoged presented a set of aerodynamic data of Javanese stops during the Linguistics Society of America Summer Institute at Cornell University in 1996, based on the speech of a bilingual Javanese/ Indonesian speaker (myself). The signal was recorded using the Macquirer analysis program and instrumentation. The analysis of breathy stops consists of three elements, namely a waveform, oral pressure, and oral airflow. Oral pressure is greatest for sounds with a high degree of oral constriction, e.g. for stops. Airflow, on the other hand, is greater when there is no impedance in the vocal tract, e.g. for vowels, compared to when there is obstruction, e.g. for consonants. (Note, however, that a fricative might have a higher degree of airflow, as it is necessary to create noise through a relatively narrow constriction.) The oral airflow during a stop would be the smallest. Figure 4.5 illustrates an aerodynamic analysis of Javanese breathy vs. clear stops (the graph was created by Ladefoged and is reproduced here with permission; some editing is added for clarification purposes).

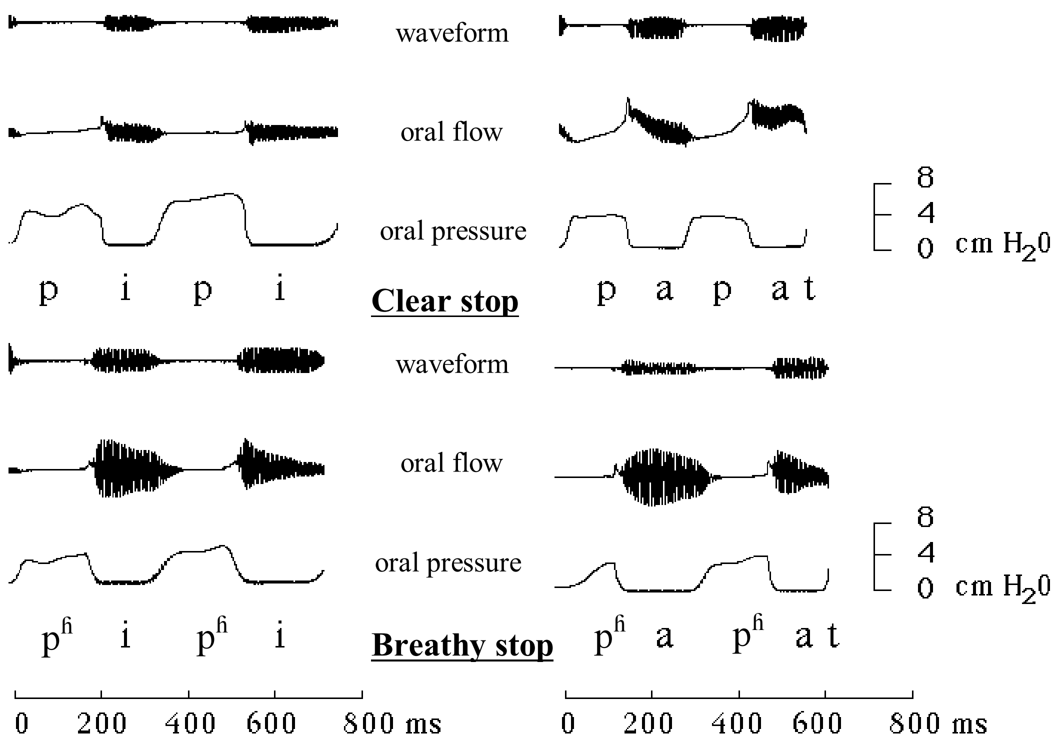


Figure 4.5: Oral pressure during Javanese clear vs. breathy stops and airflow during vowels following breathy vs. clear stops, as produced by a bilingual Javanese/Indonesian speaker (NAS)

The waveforms of the clear vs. breathy stops indicate that there is no voicing during the stop closure, consistent with other findings for Javanese stops (Fagan, 1988; Hayward, 1993; Adisasmito-Smith, 1999a). As for the oral airflow, there is none during the stop closure. For the vowels, it is smaller for those following a clear stop than for those following a breathy one. This would be due to the differences in the glottal configuration during phonation, in that there is an incomplete glottal closure for the breathy stop that allows for greater degree of airflow. This, in turn, would give rise to the increase of aperiodic noise in higher frequencies, resulting in greater noise than harmonic energy at these frequencies. The airflow data for Javanese shown in Figure 4.5 concurs with that for Gujarati presented by Fischer-Jørgensen (1967).

With respect to oral pressure during the stop closure, the clear stops are claimed to have relatively higher oral pressure than breathy stops. Based on Figure 4.4, this is the case for the clear stops in *pipi* 'cheek' and *papat* 'four' as compared to the breathy ones in *p*^{ɦ}*ip*^{ɦ}*i* 'aunt' and *p*^{ɦ}*ap*^{ɦ}*at* 'tripe', i.e. the displacement of the line from the 0 cm H_2O line is greater for the clear stops than for the breathy ones. The oral pressure for vowels is smallest due to relatively little impedance in the oral cavity. The different degree of oral pressure during the clear vs. breathy stop closure is presumably related to the differences in glottal configuration to produce the phonation contrast. Recall that the phonation contrast in Javanese is realized on the following vowel. The oral pressure during stop closure may be adjusted in anticipation of the different glottal configurations needed for the following vowel. In other words, in the production of clear vowels, greater oral pressure during the closure of the preceding stop results from an attempt to achieve a greater degree of glottal adduction. The smaller degree of glottal adduction for breathy vowels requires less oral pressure during the stop closure. For Javanese, actual quantification of oral pressure and a greater number of samples are needed to determine whether this phenomenon is consistent for all speakers, and whether the oral pressure difference for these stops is significant.

Results from these earlier studies on Javanese serve as the basis of comparison. So far, there is no available acoustic study on Indonesian stops; the results in this work would contribute to our knowledge of the acoustics of Indonesian stops. The acoustic measurements of Javanese and Indonesian stops are presented in § 4.5. First, I discuss briefly the methods of obtaining values to quantify the acoustic correlates of breathy vs. clear stops in Javanese in the next section.

4.4 Methodology

There are two main goals pursued in the present study. The first is to compare the production of Indonesian and Javanese stops by the bilingual Javanese/Indonesian speakers. The results would provide insight to the question regarding which pattern, i.e. Javanese or Indonesian, that the bilingual speakers use when they speak Indonesian. The second is to determine which acoustic parameters that are most prominent for these speakers in distinguishing stops that are acoustically breathy from those that are clear. There are a number of acoustic parameters that can be used to achieve this aim, as discussed in the previous section.

Based on the fact that previous studies show that speakers combine different strategies to produce breathy sounds and that some parameters have been found to be more reliable than others, the acoustic measurements carried out in this study are the following: (1) the fundamental frequency (F0) of the following vowel; (2) the spectral tilt, by comparing the difference between the amplitude of the first harmonic (H1) and that of the second harmonic (H2), H1-H2, and that of the first harmonic and that of the F3 peak, H1-A3; (3) the F1 bandwidth of the following vowel by comparing the difference between the amplitude of the first harmonic and that of the first formant (A1), H1-A1; (4) the harmonics-to-noise ratio (HNR), following de Krom's (1993) method, to quantify the additive noise in the frequency regions between 2-5 kHz. These measurements for (1) - (3) are taken at the 30%, 50%, and 70% points of the vowels, with the purpose of determining potential different degrees of breathiness depending on the distance from the preceding stop. The measurements for HNR target the whole vowel.

In the present study, I investigate the production of breathy sounds by the bilingual speakers from Central Java, as compared to the monolingual Indonesian speakers from Jakarta. I assume that the breathiness in the stop series of the Central and Eastern dialects of Javanese is similar, and therefore I focus on only one dialect. However, the two dialects may differ in degrees of relative breathiness or speakers of one dialect may emphasize a set of strategies with respect to breathiness and speakers from the other dialect may emphasize another. Future acoustic study may focus on potential differences between the two Javanese dialects.

In comparing the acoustic realization of Indonesian stops by the monolingual and the bilingual speakers, a question that arises is whether the acoustic parameters used to quantify relative breathiness would show a difference between the production of stops by the monolingual and the bilingual speakers. The results for the bilingual speakers may reflect the Indonesian pattern, or the Javanese pattern, or something in between. The anticipated acoustic results for Indonesian vowels following voiced/voiceless stops and for Javanese vowels following breathy/clear stops are summarized in Table 4.2.

Table 4.2: The expected results of acoustic measurements of vowels following breathy vs. clear stops

Measurements	Indonesian		Javanese	
	VCV	VNCV	VCV	VNCV
i. F0	T[1] > D[2]	N[4]T > ND	T[1] > t[3]	N[4]T > Nt
ii. Spectral tilt:				
a. H1-H2	T < D?	NT > ND?	T < t	NT < Nt
b. H1-A3	?	?	T < t	NT < Nt
iii. F1 bandwidth:				
H1-A1	T ≈ D	NT ≈ ND	T < t	NT < Nt
iv. HNR	T ≈ D	NT ≈ ND	T > t	NT > Nt

Notes:
[1]T = voiceless (clear) stop
[2]D = voiced stop
[3]t = voiceless breathy stop
[4]N = homorganic nasal

In the Indonesian case, we predict to see lower F0 for vowels following voiced stops as compared to vowels following voiceless stops. It is not clear what effect different voicing of stops would have on the following vowel, with respect to its spectral tilt, thus the question marks. Vowel spectral tilt has been found to be affected by voicing of clicks in languages like Xhosa (Jessen and Roux, 2002) and Ju|'hoansi (Miller-Ockhuizen forthcoming), whereby vowels following a voiced click exhibit greater H1-H2 as compared to vowels following a voiceless click. If the effect of different voicing of stops and clicks on the following vowel is similar, we may see that, in Indonesian, vowels following a voiced stop to have greater spectral tilt, thus greater H1-H2 (and perhaps also greater H1-A3), as compared to vowels following a voiceless stop. To date, there is no published acoustic study of stops in Indonesian with respect to their voicing effect on spectral tilt. With respect to F1 bandwidth and HNR, we anticipate vowels following voiced stops to have similar F1 bandwidth and similar HNR as compared to vowels following voiceless stops, since both types of stops are modal. In the Javanese case, we would expect vowels following a clear stop to display greater F0, smaller spectral tilt, smaller F1 bandwidth, and greater HNR, as compared to vowels following a breathy stop.

Six speakers were recorded reading Indonesian words: one male (IM_m7) and two female (IM_f6, IM_f7) monolingual speakers, and one female (CJ_f7) and two male (CJ_m6, CJ_m7) bilingual Javanese/ Indonesian speakers. (See Chapter 2 and Appendix A for background information of these speakers.) The three bilingual speakers were also recorded reading Javanese words. The set of words analyzed in this study is shown in (8). Target segments are in bold face.

(8)

Indonesian data		*Javanese data*	
[pa**d**as]	'rock'	[sɔ**kʱ**ɔ]	'k.o. tree'
[sa**d**ar]	'conscious'	[rɔ**kʱ**ɔ]	'body'
[pa**t**ah]	'broken'	[sɔ**k**ɔ]	'pillar'
[sa**t**ar]	'nonsense word'	[rɔ**k**ɔ]	'brother'
[pa**nd**as]	'nonsense word'	[sɔ**ŋgʱ**ɔ]	'support'
[sa**nd**ar]	'lean on'	[rɔ**ŋgʱ**ɔ]	'noble title'
[pa**nt**as]	'well suited'	[sɔ**ŋk**ɔ]	'suspect'
[sa**nt**ap]	'eat'	[rɔ**ŋk**ɔ]	'skeleton'

These words were each read four times, embedded in a frame sentence. The frame sentence for Indonesian is *Dibaca* ____ *saja* 'Just read ___', and for Javanese, it is *Diwaca* ___ *sepisan* 'Read ___ once'. The total number of tokens analyzed is 192 (8 words x 4 repetitions x 6 speakers) for Indonesian, and 96 (8 words x 4 repetitions x 3 speakers) for Javanese.

Acoustic analyses of the tokens were done using XWaves+. The target vowel, i.e. the final vowel, is delimited by two labels, *v2-on* at the beginning and *v2-off* at the end. The values extracted were statistically analyzed using One-Way ANOVA from the SPSS 10 statistic package. In this study, statistic significance is reached at the level of $p < .05$.

For each language, only one vowel quality for the set of data is used. This is due to the fact that the quantification of relative breathiness takes into account the frequencies of the first three formants. These formants are different for different vowel qualities. As shown earlier in Figure 3.2 in Chapter 3, high vowels have a low first formant and low vowels have a high first formant. In addition, front vowels have higher second formant values as compared to back vowels. Only the underlying low vowel /a/ (realized as [a] in Indonesian and as [ɔ] in Javanese) is focused on, due to the difficulty of measuring H1-H2 in high vowels that have low first formant values, and due to the fact that there is a greater percentage of occurrence of the low vowel. The difficulty of measuring H1-H2 in high vowels has been observed in previous studies (e.g. Ladefoged et al., 1988; Ní Chasaide and Gobl, 1997; Miller-Ockhuizen, 2002).

The central issue investigated here is the pattern of the bilingual Javanese/Indonesian speakers with respect to the production of stop consonants, particularly Indonesian ones. These bilingual speakers may show a pattern that the monolingual Indonesian speakers have, i.e. a voiced vs. voiceless contrast among the stops. However, they may show a pattern consistent with Javanese, such that the Indonesian stops have the characteristics of Javanese stops in terms of their phonation type. To examine this, I compare the production of Indonesian stops by the monolingual speakers with the production of these stops by the bilingual speakers.

The results of the breathiness measurements are divided into several sections. In § 4.5, I present the acoustic analysis of the Indonesian voiced and voiceless stops as produced by the monolingual Indonesian speakers. In § 4.6, I present the acoustic analysis of the Javanese breathy vs. clear stops as produced by the Javanese speakers. In § 4.7, the analysis of the Indonesian stops as produced by the bilingual Javanese/Indonesian speakers is presented. Values for each speaker are listed in the Appendix D.

4.5 Acoustic measurements and analyses of Indonesian voiceless/voiced stops as produced by the monolingual Indonesian speakers

The main concern in this chapter is the acoustic realizations of stops in Indonesian and Javanese with respect to breathiness. Impressionistically, it is widely assumed that Indonesian stops are modal, and the difference between the two stop series is with respect to their voicing status, involving the presence or absence of the vibration of the vocal folds. Despite this assumption, here, these stops are analyzed using the acoustic measures for breathiness, due to the impressionistic observation that these two stop series are produced as breathy vs. clear by the bilingual Javanese/Indonesian speakers. Thus, these stops are acoustically analyzed, using the breathy measures as outlined in the methodology section (§ 4.4). In this section, I focus on the monolingual speakers. The results will then be compared with those in § 4.7, where the Indonesian stops are produced by the bilingual Javanese/Indonesian speakers. In § 4.6, I focus on the realization of the breathy/clear contrast of the Javanese stops, by these bilingual speakers.

First, I present the difference in voicing status of the two stop series in Indonesian, as produced by a monolingual Indonesian speaker. The spectrograms of the Indonesian words *padas* vs. *patah*, shown in Figure 4.6, illustrate the contrast between voiced and voiceless stops in intervocalic position.

(a) (b)

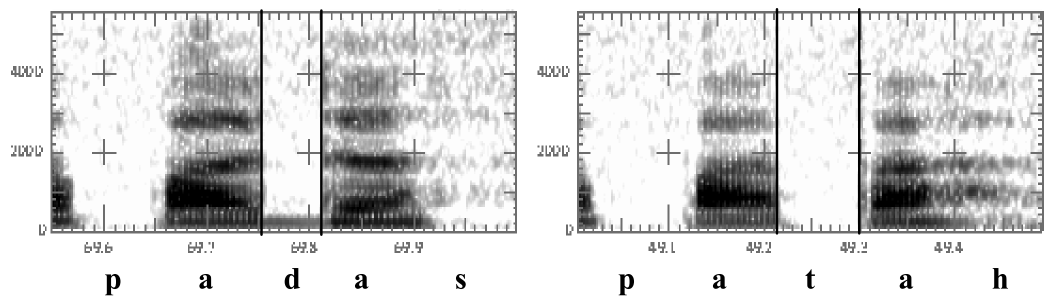


Figure 4.6: Spectrograms of Indonesian voiced vs. voiceless stops in *padas* and *patah*, as produced by the monolingual Indonesian Speaker IM_m7

During the closure of the voiced stop in *padas*, a voice bar is present, and no voice bar appears during the closure of the voiceless stop in *patah*. The distance between the two demarcating lines, representing the duration of the stops, is shorter for the voiced stop than it is for the voiceless one, as is commonly found in other languages. The difference in voicing and duration seen here is generally characteristic of the speech of the monolingual speakers and it provides support for the impressionistic description. See Chapter 5 for the acoustic analysis and detailed discussion of stop duration in Indonesian and Javanese.

With respect to the stops in NC clusters, one would expect their acoustic realization to be consistent with their voicing characteristics, i.e. the voiced stops would be realized in the spectrogram with a voice bar during the stop closure, and the voiceless ones with no voice bar. The spectrograms of the Indonesian words *pandas* and *pantas* in Figure 4.7 illustrate this.

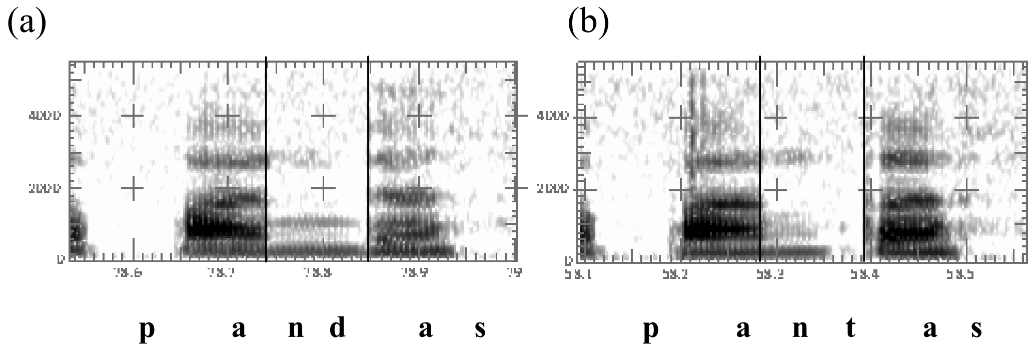


Figure 4.7: Spectrograms of Indonesian voiced vs. voiceless NC clusters in *pandas* and *pantas*, as produced by the monolingual Indonesian Speaker IM_m7

For this monolingual Indonesian speaker, the voiced stop in the root medial NC cluster (Figure 4.7a) is fully voiced and very short, while the voiceless one (Figure 4.7b) is voiceless and relatively longer in duration as compared to the voiced one. This is again in accordance with the tendency across languages.

The first acoustic measurement I present here is the fundamental frequency (F0) of vowels following the stops with different voicing. We predict that vowel F0 would be lower when they follow voiced stops than when they follow voiceless stops. The F0 results, shown in Figure 4.8, are presented for the individual speakers, since male speakers tend to have lower F0 values relative to female speakers. In these charts, a cluster of bars represents the F0 values at a particular point along the duration of a vowel, i.e. 30%, 50%, and 70% points. For each cluster, there are four bars that indicate the F0 values of a vowel following a voiceless clear stop (T), a voiced stop (D), a voiceless NC cluster (NT), and a voiced NC cluster (ND). Each bar represents an average value of 8 tokens (2 words x 4 repetitions). All bars in the charts throughout this study are represented with an error bar covering two standard deviations.

As shown in this chart, the F0 values for vowels following the voiced stops, for Speaker IM_f6, are lower than those following the voiceless stops, at all three targeted points and in both the intervocalic and NC cluster cases. The range of differences is between 4-9 Hz for the intervocalic cases and between 5-8 Hz for the NC cluster ones. Even though the tendency shown by this speaker is consistent with the tendency across languages, where voicing of stops lowers F0, the differences in F0 values here are not statistically significant.

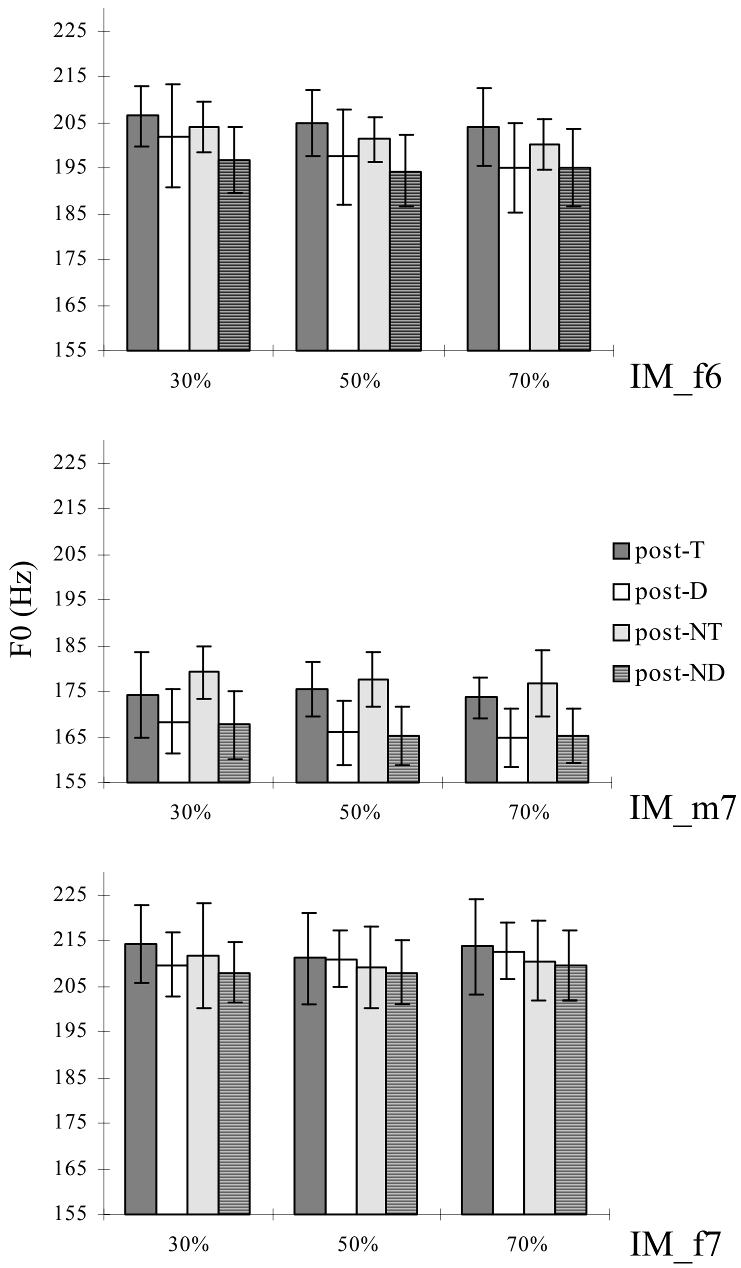


Figure 4.8: Mean F0 values (in Hz) of Indonesian vowels following voiceless (T, NT) vs. voiced (D, ND) stops, in the intervocalic and NC cluster cases, as produced by the monolingual Indonesian speakers

For Speaker IM_m7, there is a consistent pattern whereby the F0 values of vowels are lower following the voiced stops than following the voiceless ones, at all targeted points and in both the intervocalic and NC cluster cases. The F0 differences are in the range of 6-9 Hz for vowels in post-T vs. post-D cases, and 11-12 Hz for those in post-NT vs. post-ND ones. These differences are statistically significant ($p < .05$).

For Speaker IM_f7, the average F0 values at the 50% point are similar for vowels in post-T vs. post-D cases, while at the 30% and 70% points they are slightly lower for vowels in post-D cases. The F0 differences range between 0-4 Hz in these cases. In the NC cluster cases, the F0 values are lower for vowels in the post-ND cases as compared to those in the post-NT cases. The differences, ranging between 1-4 Hz, are not statistically significant. For this speaker, the greatest F0 difference occurs at the point closest to the vowel onset (30% point), suggesting that the influence of voicing on vowel F0 is short in duration (about 25 ms after vowel onset). Findings in previous studies show that F0 lowering effect on vowels may persist 100 ms after vowel onset (Hombert (1978) for English; Lofqvist (1975) for Swedish).

Overall, the three monolingual speakers show the general tendency whereby voiced stops tend to lower F0. This tendency is shown to be strongest for the male Speaker IM_m7, suggestive but not significant for IM_f6, and quite marginal for IM_f7. Given the fact that the size of sample here is quite small, it is not possible to reach a firm conclusion about this tendency.

I turn now to the analysis of spectral tilt, by measuring H1-H2 and H1-A3 values. I analyze first the measurement of H1-H2 values. In

Figure 4.9, I show the comparison of the amplitude of the two peaks for vowels following voiceless vs. voiced stops.

For Speaker IM_f6, there does not seem to be a systematic pattern. The H1-H2 values are greater for vowels following the voiced stops than following voiceless stops only in two cases, i.e. at the 30% point in the intervocalic case and at the 70% point in the NC cluster case. In these two cases, the differences are at most 1 dB. The other vowel cases show the opposite tendency. Note the high degree of variability and the overlapping of values as seen by the error bars. Accordingly, the value differences are not statistically significant.

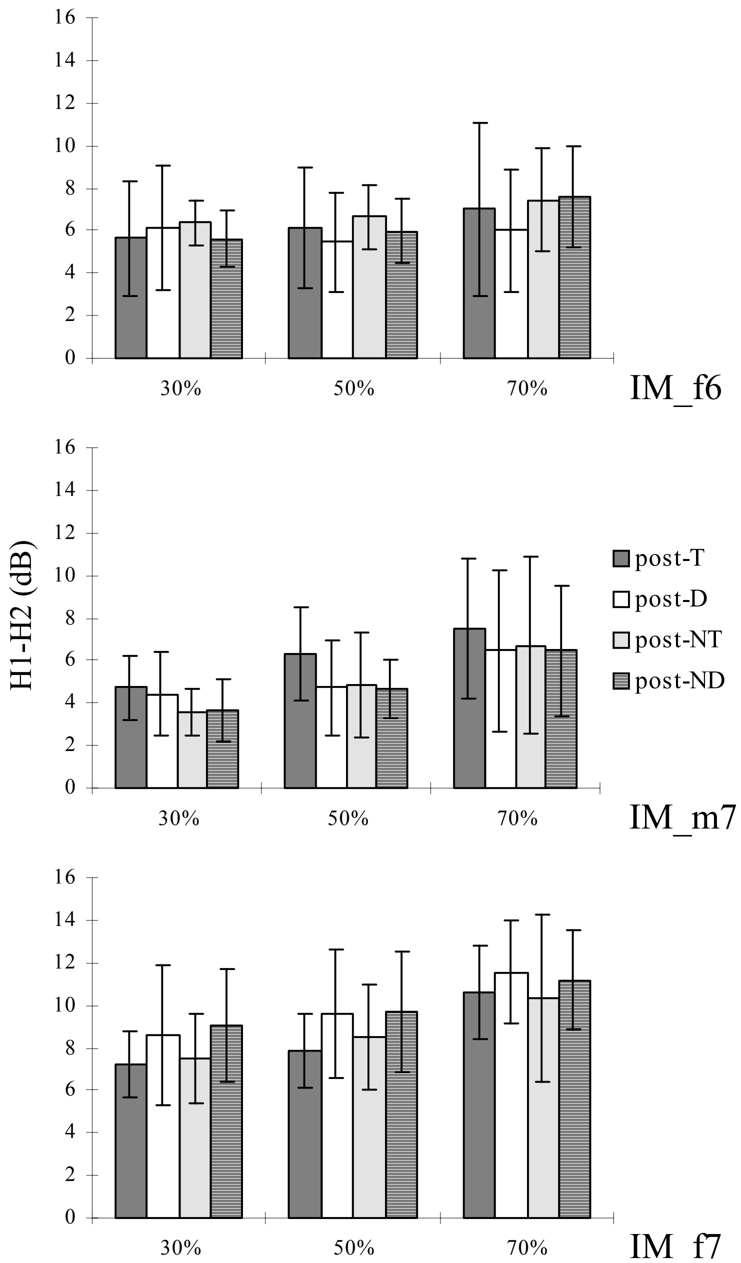


Figure 4.9: Mean H1-H2 values (in dB) for Indonesian vowels following voiceless (T, NT) vs. voiced (D, ND) stops, in the intervocalic and the NC cluster cases, as produced by the monolingual speakers

For Speaker IM_m7, the H1-H2 values are smaller for vowels following voiced stops than following voiceless stops in the intervocalic cases, at the 50% and 70% points. In the NC cluster cases, these values are similar for vowels following voiced vs. voiceless stops. The H1-H2 value differences for this speaker are not statistically significant.

For Speaker IM_f7, the H1-H2 values are consistently greater for vowels following voiced stops than following voiceless stops for all cases. The differences are in the range of 1 dB, and are not statistically significant. The result here may indicate that this female speaker is slightly breathy in her speech and this manifests in her production of Indonesian vowels.

I turn now to the analysis of spectral tilt over the first 3000 Hz. The amplitude of the first harmonic (with the frequency range of 100-500 Hz) is compared to the amplitude of the third formant (with the frequency range of 2000-3000 Hz), H1-A3. The results for the Indonesian monolinguals are provided in Figure 4.10.

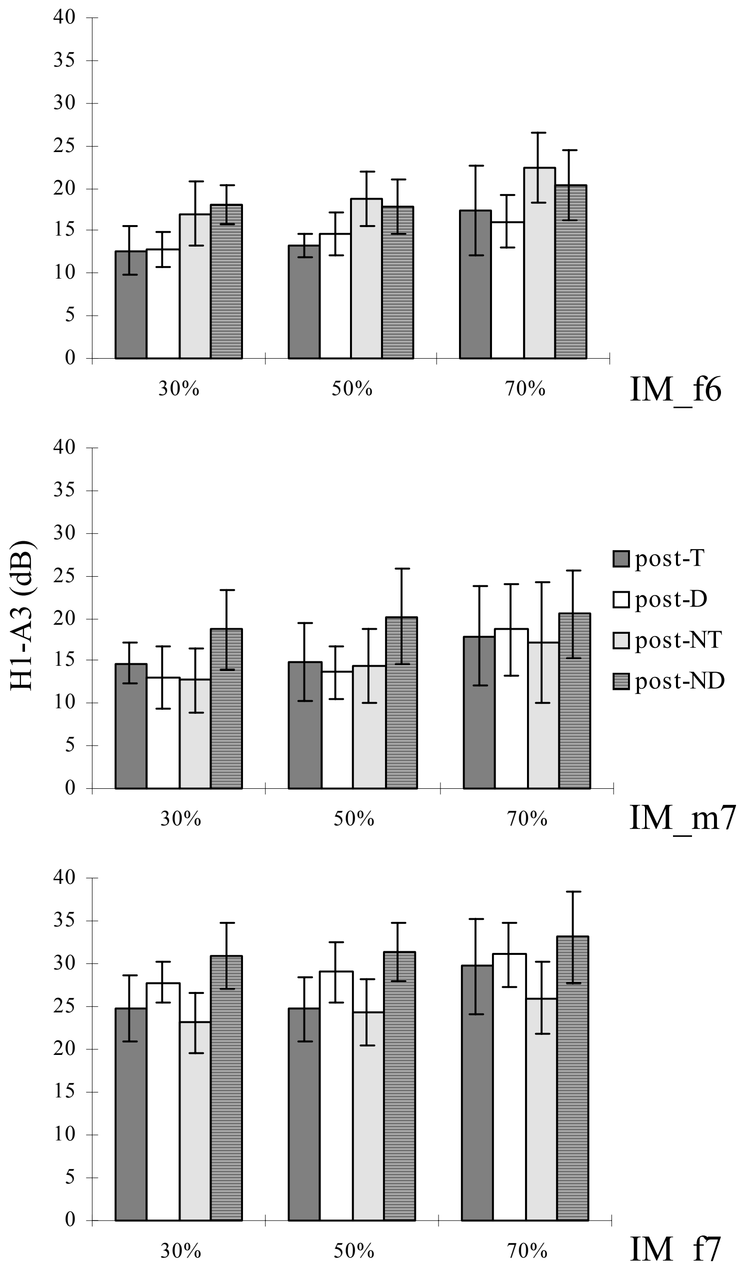


Figure 4.10: Mean H1-A3 values (in dB) for Indonesian vowels following voiceless (T, NT) vs. voiced (D, ND) stops, in the intervocalic and NC cluster cases, as produced by the monolingual Indonesian speakers

For Speaker IM_f6, there does not seem to be a consistent pattern of spectral tilt relative to voicing. The H1-A3 values are slightly greater for vowels following voiced stops in the intervocalic cases at the 30% and 50% points, and in the NC cluster cases at the 30% point, as compared to those following voiceless stops. The differences are at the most 1 dB. In the other cases, the H1-A3 values are greater for vowels following the voiceless stops than following the voiced ones. The value differences are not statistically significant.

For Speaker IM_m7, the H1-A3 values are greater for the intervocalic vowels following voiced stops as compared to following voiceless ones, at the 70% point. At the 30% and 50% points, the opposite is the case. For the NC cluster cases, the vowels following the voiced stops have greater H1-A3 values than those following the voiceless ones. The differences in these cases range from 3 dB at the 30% point to 6 dB at the 50% point. The value differences are statistically significant ($p < .05$) for vowels in the NC cluster cases, at the 30% and 50% points in the vowel.

Unlike Speakers IM_f6 and IM_m7, Speaker IM_f7 shows a systematic pattern. The H1-A3 values are greater for vowels following voiced stops than following voiceless ones, at all three targeted points and in both the intervocalic and NC cluster cases. The H1-A3 values range between 25-31 dB for the intervocalic cases and between 23-33 dB for the NC clusters. The differences contrasting the effect of the voiced vs. voiceless stops on the following vowel range between 1-4 dB for the intervocalic cases and between 7-8 dB for the NC cluster ones. Statistically, these differences are significant ($p < .05$) for the NC cases, but not for the intervocalic cases.

Comparing the three speakers whose speech is analyzed here, the range of the average H1-A3 values for Speaker IM_f7 is greater than that for the two other speakers (12-20 dB for IM_f6, 13-20 dB for IM_m7). This implies that, overall there is a greater degree of energy dampening at high frequencies for IM_f7. As discussed earlier, this energy dampening is argued to result from a relatively open glottis. This, in turn, suggests that Speaker IM_f7 may have an overall relatively breathy voice quality. The H1-H2 results for this speaker are consistent with this tendency. Considering her background (native from Jakarta, no Javanese influence, etc. -- see Appendix A, § A.2.1b), her breathy voice quality may be due to social or physiological factors, rather than due to the influence from other languages like Javanese. Further systematic studies on whether (some) monolingual female speakers of Indonesian tend to be breathier than (some of) their male counterparts would be needed. This has been found to be the case for speakers of British and American English, and Swedish (e.g. Henton and Bladon, 1985; Henton, 1987; Klatt and Klatt, 1990; Söderstein and Lindestad, 1990; Karlsson, 1994; Hanson, 1997).

An interesting tendency common to all three speakers here is the fact that the H1-A3 mean values are consistently greater, thus steeper spectral tilt at high frequencies (above 2000 Hz), for vowels following stops in the NC cases than for those following the stops in the intervocalic cases, especially for the voiced stops, and the fact that this tendency is persistent at least up to the 75% point into the vowel. One possible source for this tendency may be due to the presence of the nasal preceding the voiced stops. Stevens (2000) finds that in English, an intervocalic nasal, especially alveolar, has the effect of increasing the amplitude of F3 (i.e.

A3). However, his finding shows that this effect is present during the time interval of at the most two glottal periods following the nasal release. The finding in this dissertation shows that the steeper spectral tilt in the NC cases persists much further. It is not clear what this tendency results from.

The next acoustic measurement I present is H1-A1, which correlates with the bandwidth of vowel F1. The greater the H1-A1 value, the wider the F1 bandwidth is (Hanson, 1997). The results are shown in Figure 4.11.

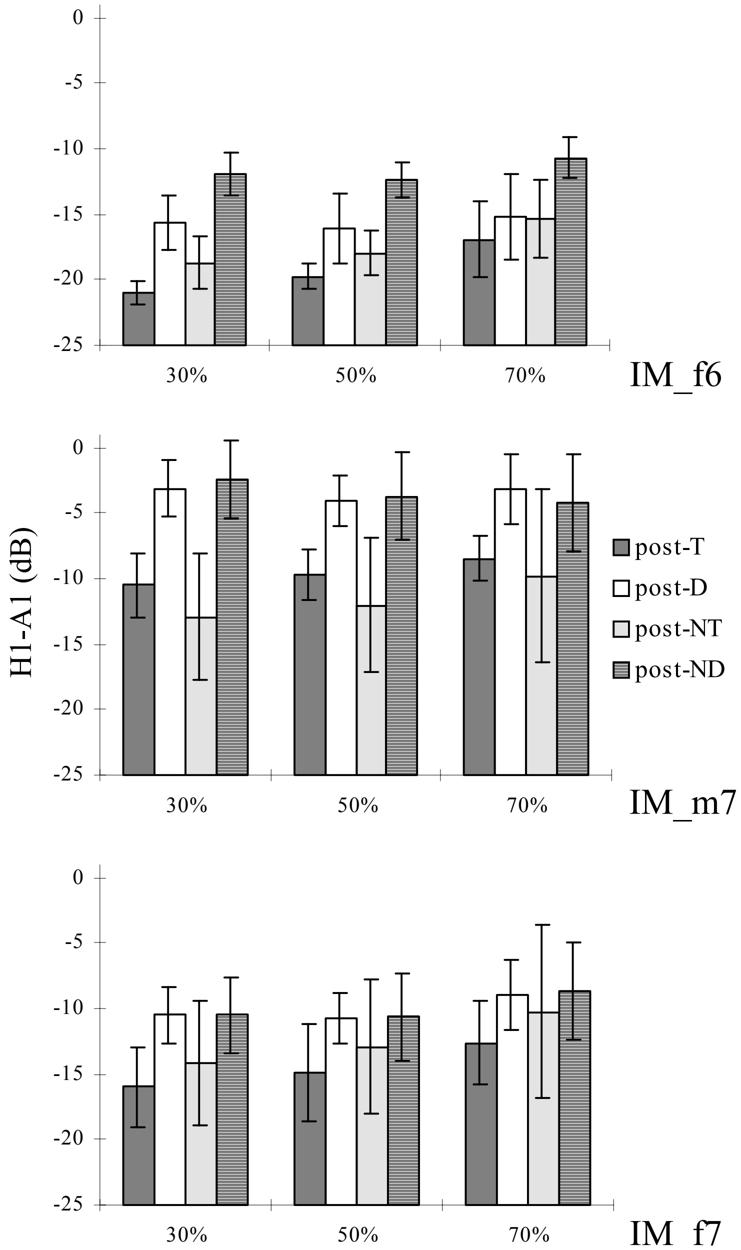


Figure 4.11: Mean H1-A1 values (in dB) for Indonesian vowels following voiceless (T, NT) vs. voiced (D, ND) stops, in the intervocalic and NC cluster cases, as produced by the monolingual Indonesian speakers

For Speaker IM_f6, the H1-A1 values are greater for vowels following voiced stops and following voiceless ones, at all targeted points and in both the intervocalic and the NC clusters. The ranges of these values are between -21 to -15 dB for the intervocalic cases and -19 to -11 dB for the NC cluster ones. The H1-A1 value differences for the intervocalic vowels in the post-T vs. post-D cases are in the range of 2-5 dB, and for those in the NC cluster cases are in the range of 4-7 dB. Statistically these differences are significant ($p < .05$) for all cases, except for the intervocalic case at the 70% point.

Speaker IM_m7 is seen to have a pattern similar to that of Speaker IM_f6. The H1-A1 values are greater for vowels following voiced stops and following voiceless ones, at all targeted points and in both the intervocalic and the NC cluster cases. The ranges of these values are between -10 to -3 dB for the intervocalic cases and -13 to -4 dB for the NC cluster ones. The differences for the intervocalic vowels in the post-T vs. post-D cases are in the range of 5-7 dB, and those in the NC cluster cases are in the range of 6-11 dB. These differences are statistically significant ($p < .05$) for all cases.

Speaker IM_f7 also shares a similar pattern relative to speakers IM_f6 and IM_m7 with respect to the H1-A1 values and vowels following the stops with different voicing. The ranges of these values are between -16 to -9 dB for the intervocalic cases and between -14 to -9 dB for the NC cluster ones. The differences are in the range of 4-5 dB for the intervocalic cases and 1-3 dB in the NC cluster ones. These differences are statistically significant ($p < .05$) only for the intervocalic cases at the 30% point.

The results here suggest that vowels following voiced stops tend to have greater H1-A1 values, indicating that these vowels have wider F1 bandwidth following voiced than following voiceless stops, as we have expected. This tendency is shown to be consistent among the three speakers, even though it is statistically significant only in some cases. It is also interesting to note that, for all three speakers, the differences in H1-A1 values are greatest at the 30% point of the vowels and smallest at the 70% point in both the intervocalic and the NC cluster cases. This would suggest that the effect of stop voicing on F1 bandwidth is greatest closer to the stop release and that the effect decreases at points further away from the release.

I now turn to the acoustic measure of harmonics-to-noise ratio to quantify noise associated with the stops. As compared to breathy phonation, we predict that the Indonesian modal stops for the monolingual speakers would have either similar HNR values for vowels following voiceless vs. voiced stops, or no systematic pattern. The results are displayed in Figure 4.12.

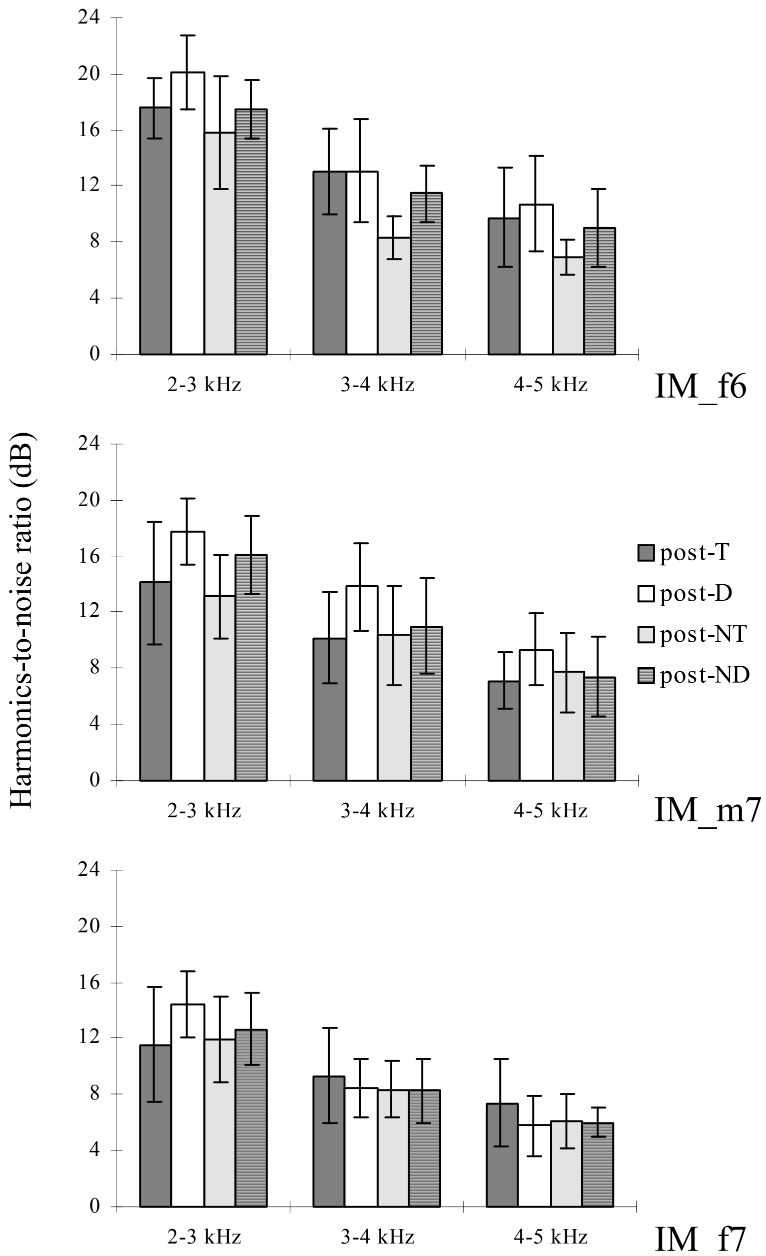


Figure 4.12: Mean harmonics-to-noise ratio (HNR) values (in dB) of Indonesian vowels following voiceless (T, NT) vs. voiced (D, ND) stops, in the intervocalic and NC cluster cases, as produced by the monolingual Indonesian speakers

For Speaker IM_f6, the HNR values are either greater (by 2dB) or comparable for the vowels following the intervocalic voiced stops as compared to those following the voiced ones. For the NC cluster cases, vowels following voiced stops have greater HNR values as compared to those following voiceless ones, with the difference between 2-4 dB. This suggests that for this speaker, vowels following voiceless stops in NC clusters tend to have slightly greater noise as compared to those following voiced ones. These value differences are statistically significant ($p < .05$) for vowels in the NC case within the 3-4 kHz range and are marginally significant ($p = .05$) for vowels in the intervocalic case within the 2-3 kHz range.

For Speaker IM_m7, the HNR values are greater for vowels following voiced stops than following voiceless stops in the intervocalic cases, at all frequency ranges, with a range of difference of 2-4 dB. In the NC cluster cases, the HNR values are greater for vowels following voiced stops within the 2-4 kHz frequency range, with a range of difference of 1-3 dB. At the 4-5 kHz range, these values are smaller by 1 dB for vowels following the voiced stops. The value differences for this speaker are marginally significant for vowels in the intervocalic cases within the 2-4 kHz range and for vowels in the NC case within the 2-3 kHz range.

For Speaker IM_f7, the HNR values at the 2-3 kHz frequency range are greater for vowels following voiced vs. voiceless stops in both the intervocalic and cluster cases, with a difference between 1-2 dB. At the 3-5 kHz frequency range, the values are either similar or lower for those following voiced stops, with the difference at the most of 2 dB. This may suggest that in higher range of frequencies (3-5 kHz), there is a slight increase of additive noise for vowels following voiced stops. The value differences for this speaker are not statistically significant.

Overall, there is a tendency of greater HNR values for vowels following voiced stops than for those following voiceless stops, for all three speakers. This suggests that there is a greater degree of noise for vowels following voiceless stops. In other words, there is a greater degree of harmonic energy than noise energy for vowels following voiced stops in the Indonesian of the monolingual speakers.

The acoustic results for the Indonesian vowels following the stops are summarized in Table 4.3. However, for ease of comparison, first I summarize briefly what we predict to see, as previously laid out in Table 4.2. Then I discuss the summary in Table 4.3. We would expect Indonesian vowels to display greater F0 following voiceless stops as compared to vowels following voiced stops. As for spectral tilt, voiced clicks in Xhosa (Jessen and Roux 2002) and in Ju|'hoansi (Miller-Ockhuizen, forthcoming) have been found to affect vowels, in that vowels following a voiced click exhibit smaller H1-H2 when compared to vowels following a voiceless click. This pattern may be observed in Indonesian, if the acoustic effect of voicing in stops and that in clicks on the following vowel are similar. Since both stop series in Indonesian are modal, we predict that vowels following voiceless stops and those following voiced stops have similar F1 bandwidth and similar HNR.

Table 4.3: Summary of the acoustic measurements of Indonesian vowels following voiced vs. voiceless stops for the monolingual speakers

	IM_f6	IM_m7	IM_f7
F0	T > D NT > ND	T > D NT > ND	T > D NT > ND
H1-H2	no pattern	T > D NT ≈ ND	T < D NT < ND
H1-A3	no pattern	no pattern NT < ND	T < D NT < ND
H1-A1	T < D NT < ND	T < D NT < ND	T < D NT < ND
HNR	T </≈ D NT < ND	T < D NT </≈ ND	no pattern NT ≈ ND

The shaded cells in this table indicate that either the results show *no pattern*, no difference between voiced vs. voiceless cases, or are opposite to the expected pattern for a clear vs. breathy contrast. A cell indicated as having *no pattern* means that the results are mixed (e.g. differences at the 30% point may be in the opposite direction, but the differences at the 70% point may be in the expected direction).

As summarized here, the results in this study indicate that, for the monolingual Indonesian speakers, vowels following voiced stops in Indonesian display the tendency of F0 lowering as compared to vowels following voiceless stops, as has been found to be a common tendency in many other languages.

For the two spectral tilt measurements used here (H1-H2 and H1-A3), the results for the three speakers differ from each other. For Speaker IM_f6, stop voicing does not seem to affect vowel spectral tilt.

For Speaker IM_m7, stop voicing affects vowel spectral tilt in the higher frequency region (i.e. F3 region) and only in the NC cases. For Speaker IM_f7, the results show that the spectral tilt for vowels following a voiced stop is greater than for vowels following a voiceless stop, in both the intervocalic and the NC cluster cases. The result of vowel spectral tilt for Speaker IM_f7 may indicate that this speaker has the tendency to be breathy. It is also possible that the result for this speaker and for Speaker IM_m7 suggest an acoustic effect of stop voicing on vowel spectral tilt. Further acoustic study would be needed to determine the ways in which voicing of stops affects the spectral tilt of the following vowel.

The overall results of vowel F1 bandwidth (measured by H1-A1) indicate that voicing of the preceding stop results in wider F1 bandwidth. As discussed earlier, one of the acoustic characteristics of breathiness is wider F1 bandwidth or a greater value of H1-A1 (e.g. Ladefoged et al., 1988; Hanson, 1997). This suggests that there are acoustic similarities between vowels following modal voiced stops and those following breathy stops (or between modal vs. breathy vowels). This would not be surprising if one takes the claim that modal and breathy phonation types represent a continuum with respect to the state of the glottis. As argued by Henton et al. (1992), within this continuum breathy sounds have a greater degree of glottal opening, as compared to modal sounds. The results here suggest that, despite the different degrees of glottal opening, this opening would result in relatively broad F1 bandwidth, as compared to the F1 bandwidth for vowels following a modal voiceless stop.

In the next section, I turn to the acoustic analysis of Javanese stops that are phonemically distinguished as either breathy or clear. The order of presentation of results follows that in this section.

4.6 Acoustic measurements and analyses of Javanese breathy/clear stops as produced by the Central Javanese speakers

Uhlenbeck (1978), based on impressionistic observations, claims that there is no voicing distinction between breathy and clear stops in Javanese. Based on an acoustic study, Fagan (1988) shows this to be the case. A pair of spectrograms is shown in Figure 4.13 to illustrate the voicing status of Javanese medial stops. The stops in the two words above are demarcated by two vertical lines. During the closure of both stops there is no voice bar. The lack of this vibration indicates that the segment is voiceless. These spectrograms are representative of all instances for all speakers recorded in this study.

(a) (b)

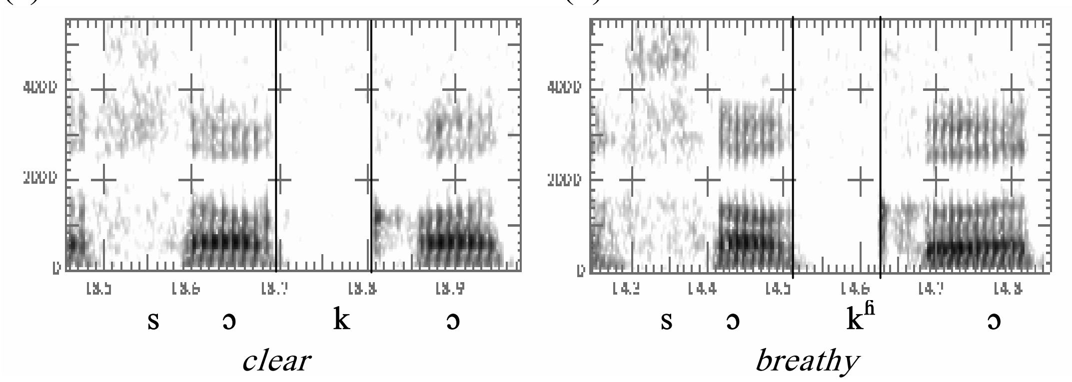


Figure 4.13: Spectrograms of the Javanese clear vs. breathy stops in [sɔkɔ] *pillar* and [sɔk^{ɦ}ɔ] *k.o. tree*, by Speaker CJ_m6

In medial NC clusters, however, the breathy stop is realized as voiced (Hayward, 1993; Adisasmito-Smith, 1999a). The set of spectrograms in Figure 4.14 shows the voicing status of the stops in NC clusters.

(a) (b)

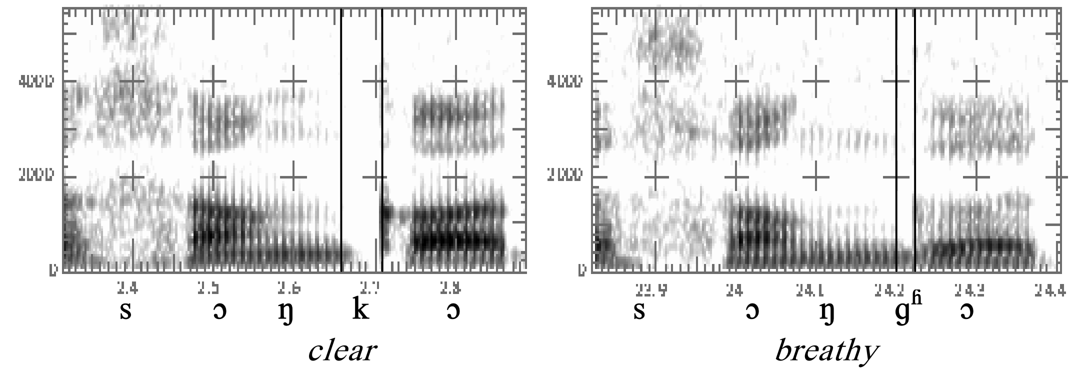


Figure 4.14: Spectrograms of Javanese clear vs. breathy NC clusters in [sɔŋkɔ] *suspect* and [sɔŋgʱɔ] *support*, by Speaker CJ_m6

During the closure of the clear stop following the homorganic nasal, there is a silent interval, which demonstrates a period of voicelessness. In contrast, during the closure of the breathy stop, there is a voice bar. Thus, the breathy stop closure is voiced when it follows a homorganic nasal. This is consistently the case for all speakers in my preliminary study and in this study. However, for the speaker in Hayward's study, there is a brief silent interval during the stop closure. Quantification of relative breathiness in both studies indicates that the stops in breathy NC clusters maintain their breathy quality. This suggests that voicing in the breathy NC cluster cases is redundant, triggered by the preceding nasal; and thus, voicing is not a separate category in Javanese. In addition to the presence of the voice bar, the duration of the breathy stop closure is shorter than that of the clear stop closure. This pattern is consistent with the general tendency whereby the duration of voiced consonants is shorter than that of their voiceless counterparts (e.g. Fischer-Jørgensen, 1954; Lehiste, 1970). While not widely noted in the literature, this is even clearer for voiced vs. voiceless stops after nasals (e.g. Cohn, 1990; Henton et al., 1992). As a cross-language phenomenon, voicing of stops in NC clusters has been found to be common (e.g. Pater, 1995; Rice, 1997; Hayes and Stivers, in progress, to name a few). The sources for this tendency have been argued to be nasal leak and velum raising (Rothenberg, 1968; Bell-Berti, 1985; Hayes and Stivers, in progress).

The rest of this section focuses on the acoustic measurements of vowels following these stops. The set of measurements taken and the order of presentation here follows that in § 4.5.

I present first the measurements of F0. As in previous sections, the results of the measurements here are not pooled across the three speakers, since one of the speakers is female, and thus tends to have higher F0 compared to the male speakers. In addition, speakers have been found to show different combinations of acoustic correlates of breathiness. Vowels following breathy stops are expected to have lower F0 values relative to those following clear stops. The results are shown in Figure 4.15. The four bars in these charts represent the F0 values of a vowel following a voiceless clear stop (T), a voiceless breathy stop (t), a clear NC cluster (NT), and a breathy NC cluster (Nt). Results are provided at the 30%, 50%, and 70% points of the vowel.

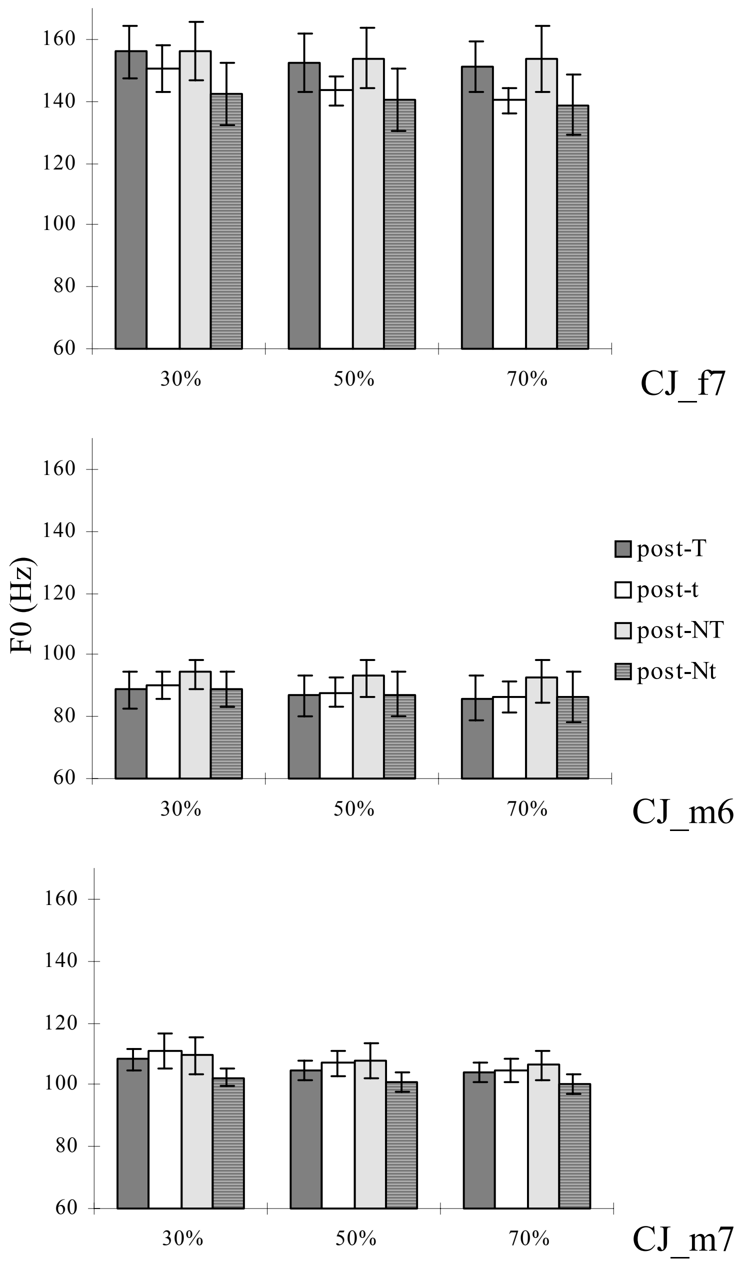


Figure 4.15: Mean F0 values (in Hz) of vowels following Javanese clear (T, NT) vs. breathy (t, Nt) stops, in the intervocalic and NC cluster cases

Comparing the F0 values of the three speakers, we can clearly see the typical difference in F0 range for speakers across gender. The F0 value range for the female speaker (CJ_f7), 140-160 Hz, is relatively higher than the range for the two male speakers, 90-110 Hz, as is typical cross-linguistically.

For Speaker CJ_f7, vowels following intervocalic breathy stops tend to have lower F0 values as compared to those following the clear ones. Vowels following breathy NC clusters also tend to have lower values relative to the clear ones. The differences range between 6-11 Hz in vowels following the intervocalic consonants and between 13-15 Hz for the vowels following clusters. These differences are statistically significant for the NC cluster cases, but not for the intervocalic cases ($p > .05$).

Speaker CJ_m6 is similar to Speaker CJ_m7 in that in the intervocalic cases, vowels following breathy stops have higher F0 values as compared to those following clear ones, even though the differences are very small. In the NC cluster cases, the vowels following the breathy stops tend to have lower F0 values relative to those following the clear ones, again as expected with a difference of 6-7 Hz. The differences are not statistically significant for either the intervocalic and NC cluster cases.

For Speaker CJ_m7, the F0 values of vowels following the intervocalic breathy stops and those following the clear ones are similar, with the differences of 2 Hz at the most. Following the NC clusters, the vowels have lower F0 values in the breathy cases than in the clear ones, as expected. The differences in the cluster cases are between 6-7 Hz, and they are statistically significant.

The results here show that in the intervocalic cases, only one out of three speakers show the expected pattern in a statistically robust way, with respect to F0 lowering. In the NC cluster cases, all three of them do.

Recall that breathy stops in Javanese are acoustically voiceless. Consequently, the F0 lowering of Speaker CJ_f7 could not result from the different voicing of the stops, and thus it is due to the different phonation type of the stops, i.e. breathy vs. clear. With respect to the F0 lowering in the NC cluster cases, one may argue that the slightly greater differences for Speaker CJ_f7 (13-15 Hz) as compared to the intervocalic ones (6-11 Hz), are due to the effect of voicing compounded with the effect of breathiness.

The pattern shown by the male speakers for the intervocalic cases indicates that there is no systematic F0 lowering for vowels following breathy stops. This is similar to the case of the speakers of Wa (Watkins, 1998, 2002), whereby only some speakers' productions exhibit F0 lowering for breathy vowels. For these male speakers, the F0 values of the breathy stops are consistently lower than those of the clear ones in the NC cases. Parallel to the NC cases for CJ_f7, I argue that the F0 lowering in the NC cases for the male speakers results from the voicing effect; that is to say that the breathy quality of the stops that are acoustically realized as voiced in the NC cases is the reason for the F0 lowering of the following vowels.

The results shown here mirror those in my preliminary acoustic study (Adisasmito-Smith, 1999a), in which a female speaker shows the F0 value difference as predicted (i.e. lower for vowels following breathy stops), while the male speakers do not consistently exhibit this pattern. It is not clear whether the division across the male vs. female speakers found here and in the previous study is coincidental, due to physiological differences between male and female speakers, or whether it serves as a social marker, as discussed earlier in § 4.2, or due to a combination of several factors. Note that it is NOT the case that the lowering of F0 values in the production of breathy sounds does not occur among male speakers cross-linguistically. Male speakers in Gujarati (Fischer-Jørgensen, 1967), in Hmong (Huffman, 1987), and in Javanese (Hayward, 1993; Wayland et al., 1994) do show the pattern of F0 lowering for breathy sounds.

I turn now to the measures of spectral tilt, where the amplitude of the first harmonic or the fundamental is compared to that of the second harmonic (H1-H2), and to that of the third formant peak (H1-A3). I first present the results of H1-H2, and then I present the results of H1-A3. In the environment of a breathy sound, the H1-H2 values would tend to be greater for breathy sounds as compared to clear ones, as illustrated earlier in Figure 4.2. The results are presented in Figure 4.16.

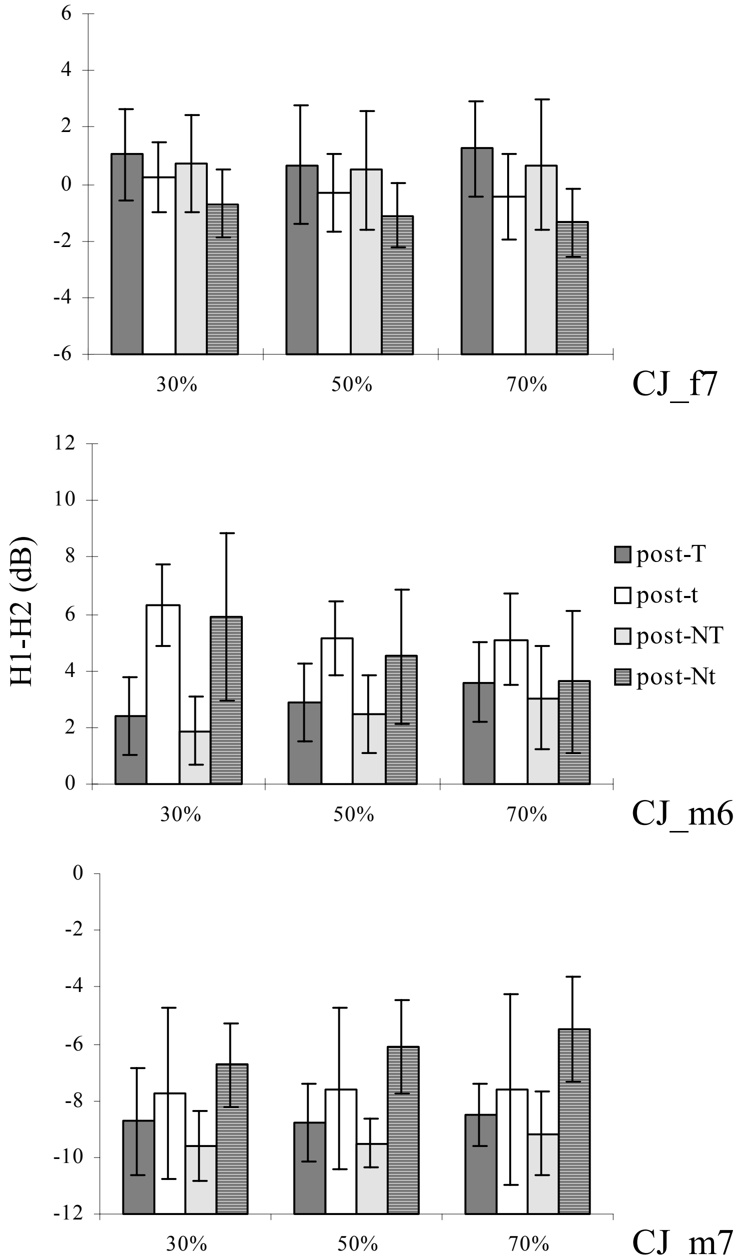


Figure 4.16: Mean H1-H2 values (in dB) for Javanese vowels following clear (T, NT) vs. breathy (t, Nt) stops, in intervocalic and NC cluster cases

Note that while the ranges of values for the three speakers are different, i.e. the range for Speaker CJ_f7 is close to zero, for Speaker CJ_m6 all above zero, and for Speaker CJ_m7 all below zero, the y-axis in each of the charts is on a 12-point scale. The difference in the minus vs. positive range of values may indicate that the speakers whose H1-H2 value range is positive are breathier than those whose value range is negative. To ascertain whether this is the case, a perceptual study would be needed.

For Speaker CJ_f7, the H1-H2 values at all three points in the vowel are greater for the clear stops than for the breathy ones, in both the intervocalic and NC cluster cases. The H1-H2 value is greatest for vowels following the clear NC clusters, and is smallest for vowels following the breathy NC clusters, both at the 70% point. The differences of H1-H2 values for post-T vs. post-t and for post-NT vs. post-Nt cases are at the most 2 dB, which are relatively small though not necessarily imperceptible. Statistically, the differences between H1-H2 values for vowels following clear vs. breathy stops are not significant for the intervocalic and NC cluster cases at all three points. The tendency shown by this speaker is contrary to the expected pattern, even though the differences are small and not statistically significant. If the small differences are a reliable tendency, this would indicate that spectral tilt at the lower frequencies is not a gauge for the relative breathiness of this speaker.

For Speaker CJ_m6, the H1-H2 values are greater for vowels following breathy stops than following clear ones, at all three points and for both the intervocalic and NC clusters. The greatest H1-H2 value is 6 dB for vowels following the intervocalic breathy stops, and the smallest is 2 dB for vowels following the clear NC clusters, both at the 30% point. The differences of H1-H2 values are greatest (of 4 dB) between post-T vs.

post-t and post-NT vs. post-Nt cases at the 30% point, and smallest (of almost 1 dB) between post-NT vs. post-Nt case at the 70% point. Statistical analysis indicates that the differences are significant ($p < .05$) for both the intervocalic and NC cluster cases at the 30% point. The pattern shown for Speaker CJ_m6 nicely illustrates the difference in relative breathiness between breathy and clear stops in that the breathiness effect on the following vowel is greatest at a point closer to the stop and becomes gradually less at a point further from the stop.

The results for Speaker CJ_m7 exhibit a similar pattern in that the H1-H2 values are greater for vowels following breathy stops than following clear ones, at all three points and for both the intervocalic and NC cluster cases. The greatest H1-H2 value is -5 dB for vowels following the intervocalic breathy stops, and the smallest is almost -10 dB for vowels following the clear NT clusters. The differences of these values are largest for post-T vs. post-t case at the 50% point (almost 4 dB), and smallest for post-NT vs. post-Nt case at the 30% point (3 dB). Statistical analysis indicates that these differences are significant ($p < .05$) for the NC cluster cases at all three points.

Overall, the spectral tilt at the lower frequencies is a good measure for relative breathiness for the male speakers here. However, it does not seem to be the case for the female speaker in this study. As with the results for F0 values discussed earlier, this cross-gender division among the speakers may be coincidental, but it may also be gender-related. A pool of a greater number of male and female speakers would be needed to draw a definitive conclusion.

Now I turn to the measurements of the spectral tilt at higher frequencies, by comparing the amplitude of the first harmonic with that of the third formant, H1-A3. As with the H1-H2 values, a vowel would tend to have greater H1-A3 values when it follows a breathy stop, as compared to when it follows a clear stop. The H1-A3 results are provided in Figure 4.17.

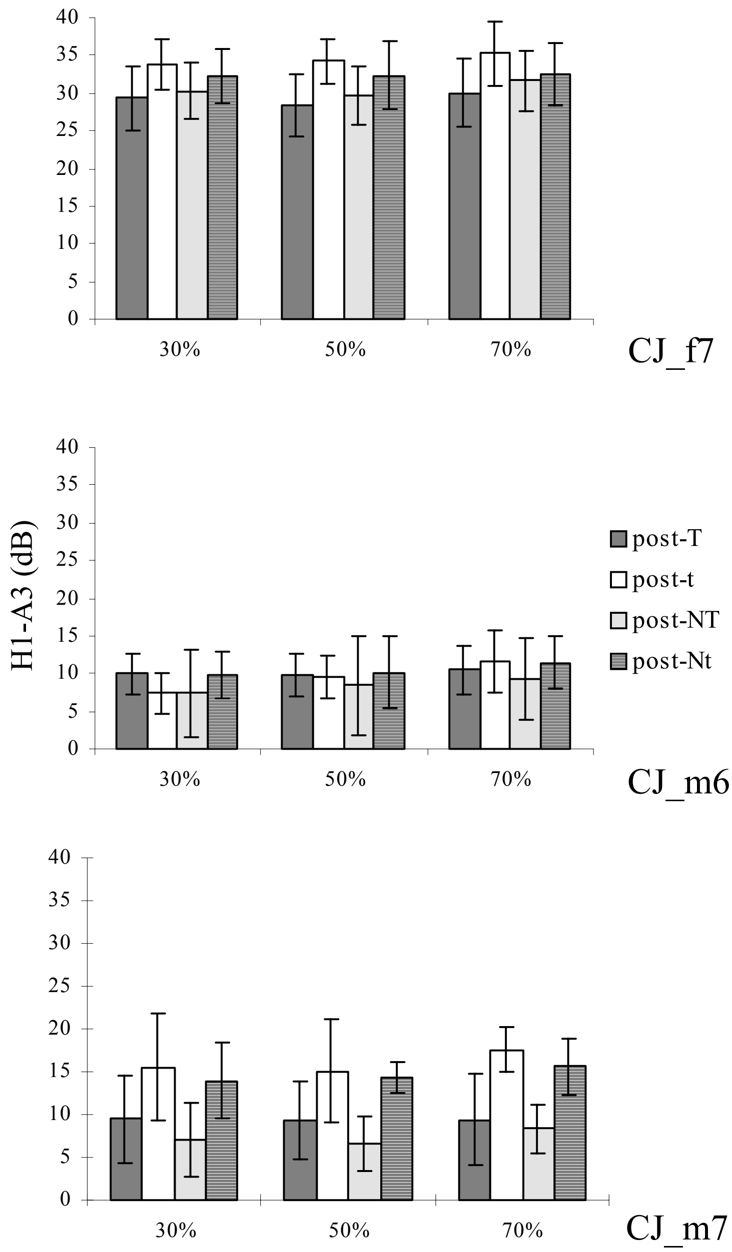


Figure 4.17: Mean H1-A3 values (in dB) of Javanese vowels following clear (T, t) vs. breathy (t, Nt) stops, in intervocalic and NC cluster cases

For Speaker CJ_f7, the H1-A3 values are greater for vowels following breathy stops than following clear stops, at all three points and for both the intervocalic and NC cluster cases. The greatest H1-A3 value of 34 dB is for the vowels in post-t case at the 50% point, and the smallest value of 29 dB is for vowels in post-T case at the 30% point. The range of differences is around 5 dB for vowels in the intervocalic cases, and it is between 1-4 dB in the NC cluster cases. These differences are statistically significant ($p < .05$) only for the intervocalic case at the 50% point.

The pattern of the H1-A3 values for vowels following the clear and breathy stops is not systematic for Speaker CJ_m6. Comparing the vowels in post-T vs. post-t cases, their H1-A3 values are greater in post-T cases at the 30% and 50% points, the opposite of what is predicted. At the 70% point, the H1-A3 value is greater in the post-t case by 1 dB. In the NC cluster cases, H1-A3 values are greater for vowels in post-Nt case than for those in post-NT case, as expected. The range of the differences of the mean values is between 1-2 dB, which is quite small, and the distributions are overlapping as seen by the error bars. Note the variability of the H1-A3 values as seen by the error bars. Accordingly, the value differences are not statistically significant.

Speaker CJ_m7's productions are similar to Speaker CJ_f7's productions in the patterning of F3 amplitude lowering, but with greater magnitude. The greatest H1-A3 value of 18 dB is for a vowel in the post-t case at the 70% point in the vowel, and the smallest of 7 dB is for vowel in the post-NT case at the 50% point. The differences are around 7 dB for the intervocalic cases and 5-8 dB for the NC cluster cases. The differences are statistically significant ($p < .05$) for all cases at all three points, as suggested by the small amount of overlap seen in the error bars.

The H1-A3 results suggest that F3 amplitude is a reliable indicator of relative breathiness for Speaker CJ_m7. For Speaker CJ_f7, even though the results follow the expected pattern, the differences are relatively small. F3 amplitude does not seem to be a reliable indicator of relative breathiness for Speaker CJ_m6, consistent with the pattern shown by this same speaker in the previous acoustic study (Adisasmito-Smith, 1999a).

The next measurement that I present is the comparison of the amplitude of the first harmonic to that of the first formant (H1-A1), which is claimed by Hanson (1997) to be linked to the vowel F1 bandwidth. Hanson shows that broader F1 bandwidth correlates with greater H1-A1 values in English. Breathy vowels have broader F1 bandwidth in Hmong (Huffman, 1986), and thus are predicted to have a relatively greater H1-A1 value as compared to clear vowels in Javanese. Results for H1-A1 are presented in Figure 4.18. Note that similar to the charts presented in Figure 4.16, the ranges of values for these speakers, the female vs. the male speakers in particular are different. However, the y-axis scale in each of these charts covers a 22-point range, although the actual scale is different.

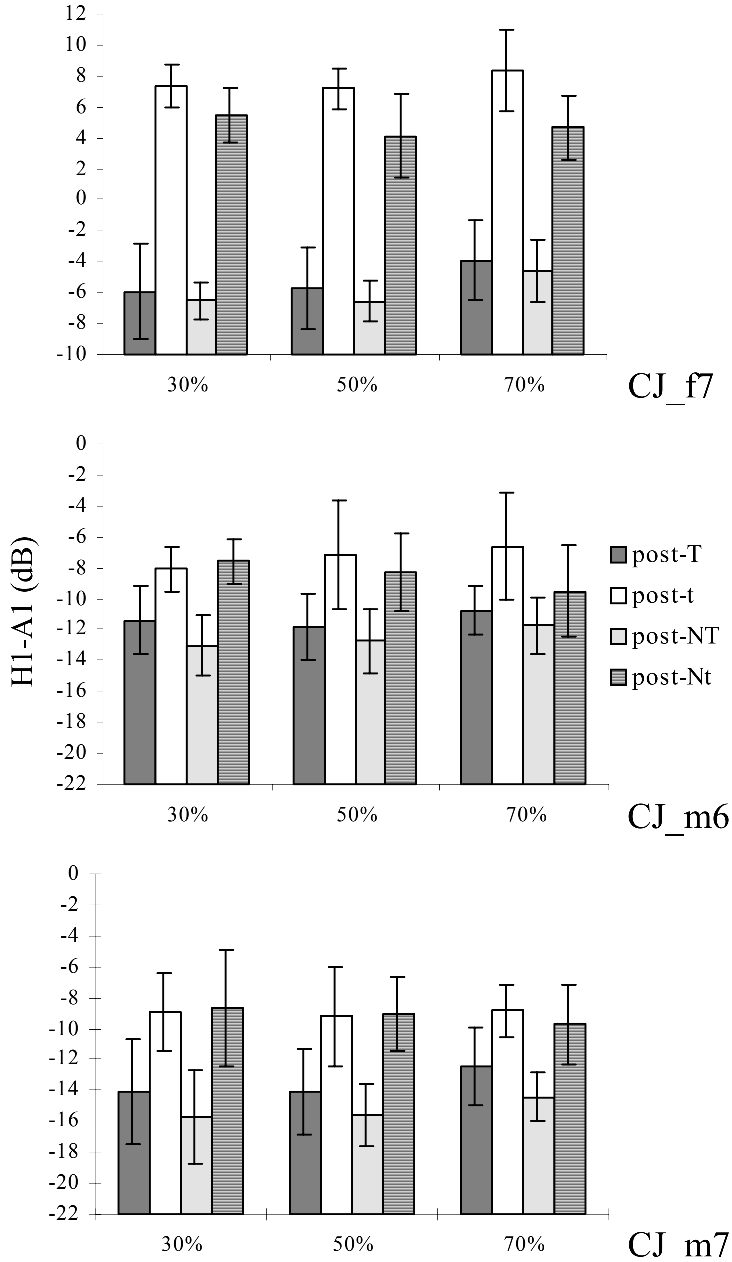


Figure 4.18: Mean H1-A1 values (in dB) of Javanese vowels following clear (T, NT) vs. breathy (t, Nt) stops, in intervocalic and NC cluster cases

For Speaker CJ_f7, the H1-A1 values are greater for vowels following breathy stops than following clear stops, in both the intervocalic and the NC cluster cases. The greatest H1-A1 value of 8 dB is for the vowels following the intervocalic breathy stops at the 70% point, and the smallest H1-A1 value of -6 dB is for the vowels following the clear NC clusters at the 30% and 50% points. The differences of these values between vowels following clear vs. breathy stops range between 12-13 dB for the intervocalic cases and between 9-12 dB for the NC cluster cases. These differences are much greater compared to those of H1-H2 values for this speaker, as presented earlier in Figure 4.9. These differences are statistically significant ($p < .05$) for both the intervocalic and NC cluster cases at all three points.

The results for Speaker CJ_m6 display a similar pattern as the results for Speaker CJ_f7, but the magnitude of differences is not as great. The greatest H1-A1 value of -6 dB is for vowels in the post-t case at the 70% point, and the smallest value of -13 dB is for vowels in the post-NT case at the 30% point. The differences in H1-A1 values range between 3-5 dB for the intervocalic cases and between 2-5 dB for the NC cluster cases. These differences are statistically significant for all ($p < .05$), except for the NC cluster case at the 70% point.

The results for Speaker CJ_m7, like the results for the other two speakers, show that the H1-A1 values are greater for vowels following breathy stops than following clear stops, at all three targeted points in the vowel and in both the intervocalic and NC cluster cases. The greatest H1-A1 value of -4 dB is for vowels in the post-t cases at all three points, and the smallest value of -16 dB is for vowels in the post-NT case at the 50% point. The differences in H1-A1 values range between 8-10 dB for the intervocalic cases and 4-6 dB for the NC cluster cases. These differences are statistically significant ($p < .05$) in both cases at all three points. Based on the results for the three speakers shown here, one would conclude that the acoustic measure H1-A1 indicates the distinction between vowels following breathy stops and those following clear stops in Javanese.

Turning to the measurement of additive noise as an indicator of relative breathiness, I present the harmonics-to-noise ratio (HNR) values, using the algorithm proposed by de Krom (1993). The results are shown in Figure 4.19. What we predict to see is that breathy sounds, having relatively greater noise, would show lower HNR values as compared to non-breathy ones.

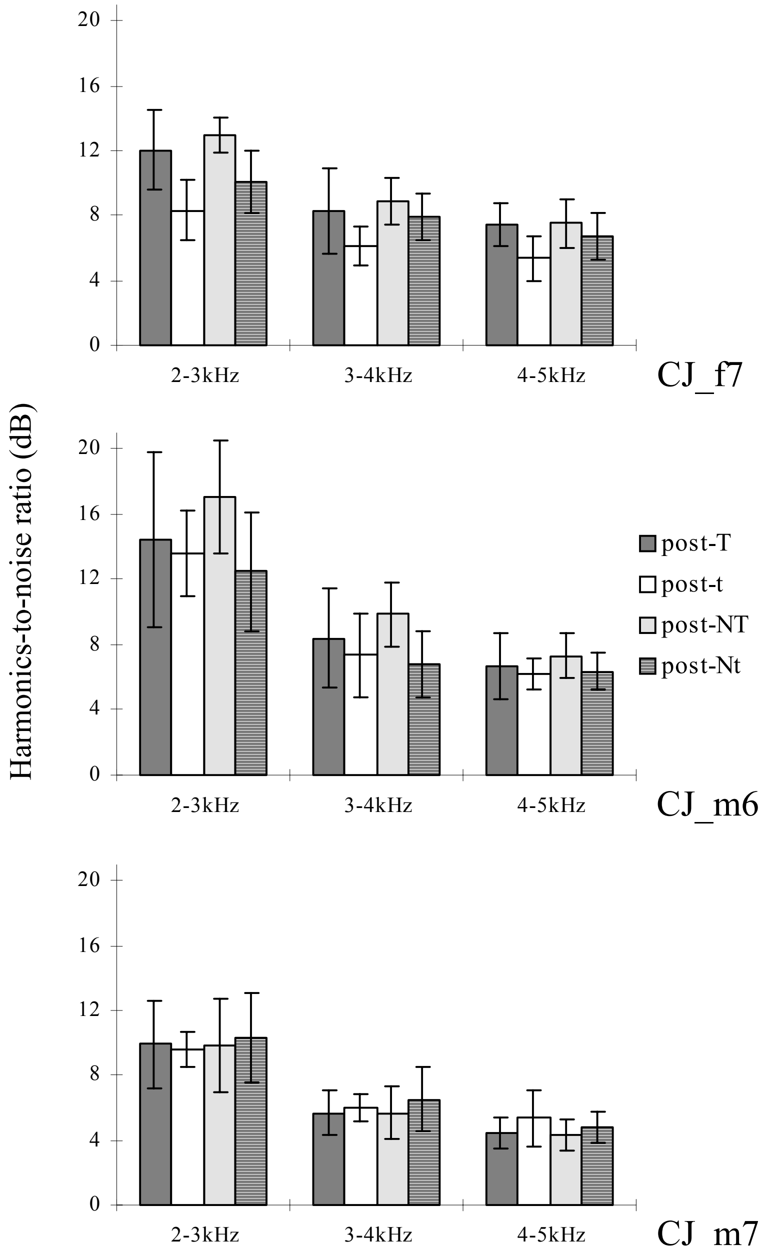


Figure 4.19: Mean harmonics-to-noise ratio (HNR) values (in dB) of Javanese vowels following clear (T, NT) vs. breathy (t, Nt) stops, in intervocalic and NC cluster cases

For Speaker CJ_f7, the HNR values are greater for vowels following clear stops than following breathy stops, in both the intervocalic and NC cluster cases, within all targeted frequency ranges. The differences range between 2-4 dB for the intervocalic cases and 1-3 dB for the NC cluster cases. Statistical analysis indicates that the differences are significant ($p < .05$) for the intervocalic cases at the 30% and 70% points, and for the NC cluster cases at the 30% point.

For Speaker CJ_m6, the HNR values are also greater for vowels following clear stops than following breathy stops, in both the intervocalic and NC cluster cases, at all targeted frequency ranges. As can be observed here, some of the differences are quite small. The differences are only 1 dB for the intervocalic cases and range between 1-4 dB for the NC cluster cases. The differences are not statistically significant for all cases at all three points.

The results for Speaker CJ_m7 are different from the results for the other two speakers in that vowels following the intervocalic clear stops show smaller HNR values as compared to those following the breathy ones, and the differences are at the most 1 dB. None of these differences reaches statistic significance.

The HNR results suggest that noise accompanies the production of vowels following breathy stops for Speakers CJ_f7 and CJ_m6, but not for Speaker CJ_m7. The summary of the acoustic measures for relative breathiness for each speaker is presented in Table 4.4. Shades indicate that the results are not in the expected direction.

Table 4.4: Summary of the acoustic measurements of Javanese vowels following breathy vs. clear stops for the Javanese speakers

	CJ_f7	CJ_m6	CJ_m7
F0	T > t NT > Nt	T ≈ t NT > Nt	T ≈ t NT > Nt
H1-H2	T > t NT > Nt*	T < t NT < Nt	T < t NT < Nt
H1-A3	T < t NT < Nt	no pattern NT < Nt*	T < t NT < Nt
H1-A1	T < t NT < Nt	T < t NT < Nt	T < t NT < Nt
HNR	T > t NT > Nt	T > t NT > Nt	T </≈ t NT < Nt

Note:
* small mean value differences

In summary, the overall results for F0 show it is lower for vowels following a breathy stop as compared to vowels following a clear stop. This is the case for one out of three speakers in the intervocalic case and for all speakers in the NC cluster case. As I argued earlier, the F0 lowering in the NC cluster cases is due to the acoustic voicing of the breathy stops when immediately following a homorganic nasal. With respect to spectral tilt, the three speakers are different in whether the lower or the higher frequencies bear the effect of the relative breathiness. Both lower and higher frequencies are affected by breathiness for only one speaker. H1-A1 values, which are linked to F1 bandwidth differences (Hanson, 1997), are shown to be greater in the breathy cases for all three speakers. HNR values indicate that two out of the three speakers show the pattern expected where breathy vowels, with greater rate of airflow and thus greater rate of noise, tend to have lower HNR values. Thus, the overall results here highlight the fact that each speaker produces the breathiness effect, albeit using different strategies.

In the next section, I present the acoustic analysis of the Indonesian stops as produced by the bilingual Javanese/Indonesian speakers. One would see, here, whether the acoustic realization of the phonemically voiced vs. voiceless pattern in Indonesian stops by these bilingual speakers is similar to that by the monolingual speakers, whether it is influenced by the pattern of Javanese stops, or whether the bilingual speakers use a pattern different from what we have seen in § 4.5 and § 4.6.

4.7 Acoustic measurements and analyses of Indonesian voiced/voiceless stops as produced by the bilingual Javanese/Indonesian speakers

As I have discussed earlier, Javanese stops that are contrastive with respect to breathiness are acoustically voiceless, in the sense that during the stop closure the vocal folds do not vibrate and thus no voice bar is visible in the spectrogram. Indonesian stops are generally claimed to be contrastive with respect to voicing. What we would expect to see is that during the closure of the voiced stop, a voice bar would be present. We have seen this to be the case for the monolingual Indonesian speakers in Figure 4.5. A representative pair of Indonesian stops for Javanese/Indonesian bilingual speakers is presented in Figure 4.20. The target consonants are demarcated by two vertical lines.

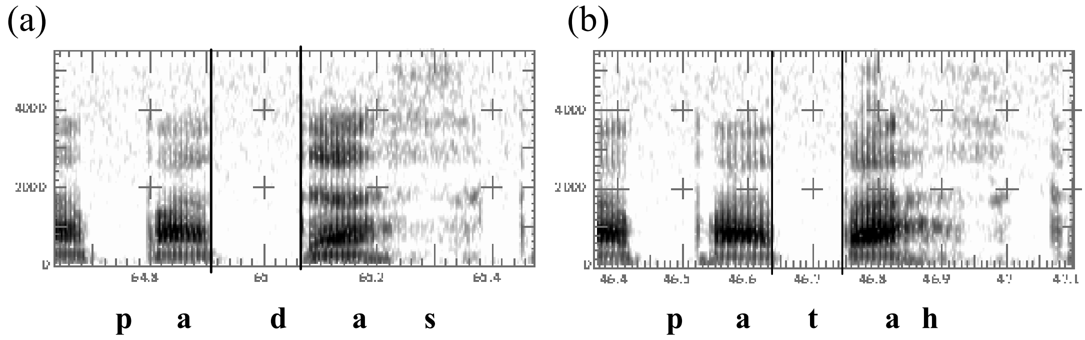


Figure 4.20: Spectrograms of the Indonesian voiced stop in *padas* vs. the voiceless one in *patah*, as produced by the bilingual Javanese/Indonesian Speaker CJ_m6

As can be observed, there is no voice bar during the closure of both the voiced and voiceless stops in the Indonesian words *padas* and *patah*, when produced by the bilingual Javanese/Indonesian Speaker CJ_m6. This lack of voicing for the Indonesian voiced stops is the case in all Indonesian tokens with “voiced” stops for this speaker, as well as these tokens for Speakers CJ_f7 and CJ_m7. In other words, for these bilingual speakers, Indonesian voiced stops are acoustically voiceless in the intervocalic position. This pattern is consistent with that of other bilingual Javanese/Indonesian speakers (Adisasmito-Smith, 1999a). The timing pattern of the Indonesian voiced vs. voiceless stops as produced by the bilingual speakers shows that they are of similar duration. In the illustration in Figure 4.20, the Indonesian voiced stop /d/ is actually slightly longer than its voiceless counterpart, opposite of what would be expected in a typical voicing contrast. See Chapter 5 for systematic duration measurements.

What, then, distinguishes the two series of Indonesian stops for the bilingual Javanese/Indonesian speakers? It is possible that these bilingual speakers ‘transfer’ the stop distinction of Javanese into Indonesian. That is to say that in order to maintain the contrast between the two stop series in Indonesian, these stops may be distinguished as breathy vs. clear rather than voiced vs. voiceless, for the bilingual Javanese/Indonesian speakers. Note that, impressionistically, the productions of Indonesian voiced stops by most bilingual Javanese/Indonesian speakers are rather breathy, as is the case with the three speakers included in this study. Based on this, one may propose that the Indonesian voiced stops are voiceless and breathy. The measurements in this section are dedicated to finding out whether the Indonesian voiced stops are in fact acoustically similar to the Javanese breathy stops, for the bilingual speakers.

In contrast to the intervocalic case, when the Indonesian voiced stop immediately follows a homorganic nasal, it is realized as voiced for the Javanese/Indonesian bilinguals, with the voice bar present during the nasal closure all the way to the onset of the stop release, as shown in Figure 4.21a. The voiceless stop following the homorganic nasal is realized as voiceless, indicated by the absence of the voice bar following the offset of the nasal up to the onset of the stop release, as shown in Figure 4.21b.

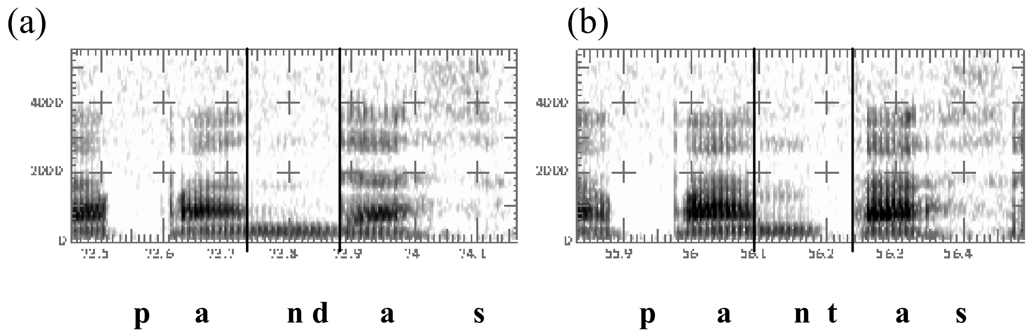


Figure 4.21: Spectrograms of an Indonesian voiced NC cluster in *pandas* and a voiceless one in *pantas*, as produced by the bilingual Javanese/ Indonesian Speaker CJ_m6

One may argue that the voicing of stops in NC clusters in this case is the result of the bilingual speakers' effort to be 'faithful' to the voicing characteristic of Indonesian stops. However, since the acoustic realization of the intervocalic stops is 'faithful' to those in Javanese, it seems more likely that the voicing of Indonesian stops in NC clusters for the bilingual speakers is triggered by the preceding homorganic nasal, as is the case for the Javanese breathy stops in NC clusters. The results of the acoustic measurements would reflect whether the Indonesian stops in NC clusters are realized with a clear vs. breathy contrast, or with just the voicing contrast. If the stops are modal (i.e. not breathy) for the bilingual speakers, we would expect to see systematic differences.

Comparing the acoustic realizations of the Javanese stops, as shown in § 4.6 earlier, with those of the Indonesian stops by the bilingual speakers, we can conclude that the realization of Indonesian stops, at least during the stop closure, are influenced by the Javanese pattern for these speakers. In this section, I investigate whether the influence also extends to other acoustic realizations, with respect to relative breathiness, in particular. The acoustic measurements with respect to relative breathiness are carried out on the vowel following the stops. The set of measurements taken and the order of presentation here also follow that in the previous two sections. Note that in this particular section, I refer to the Indonesian voiced stops as “D” because these stops, phonemically voiced, are acoustically voiceless for the bilingual speakers. First, I discuss the results of F0 measurements, shown in Figure 4.22.

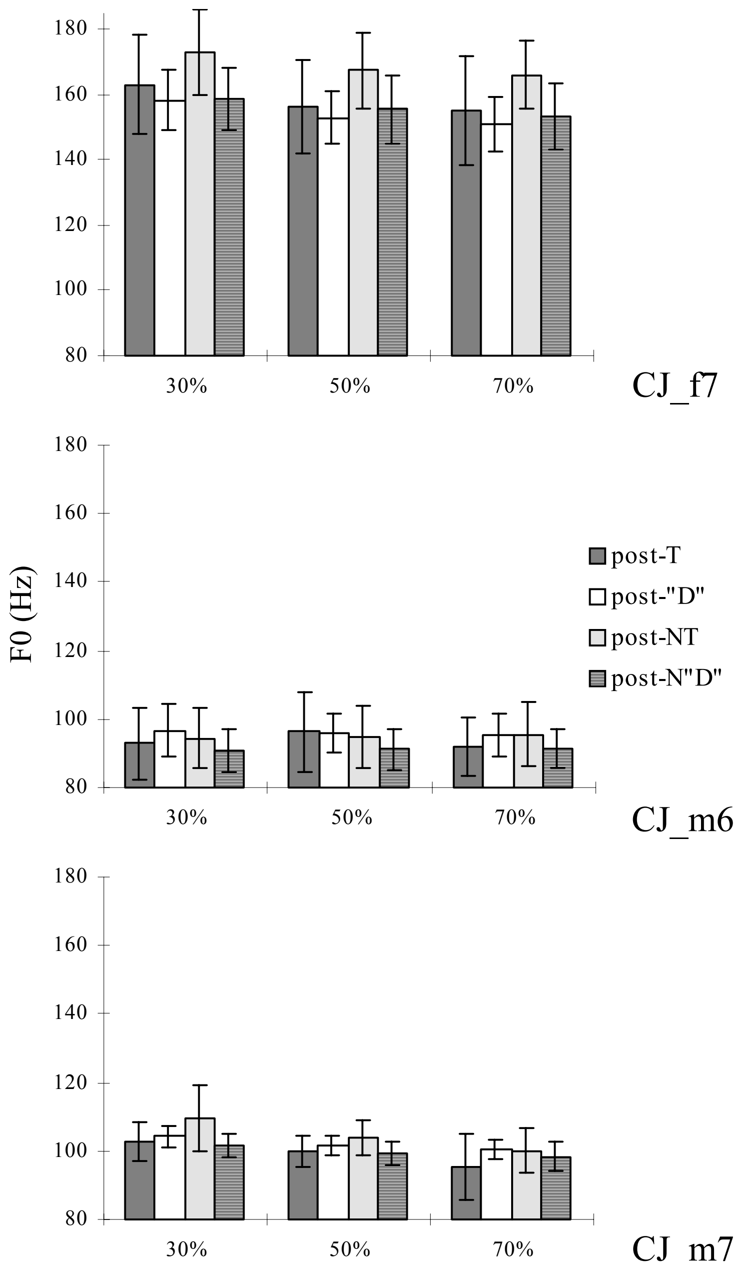


Figure 4.22: Mean F0 values (in Hz) of vowels following Indonesian voiceless (T, NT) vs. "voiced" ("D", N"D") stops, in the intervocalic and the NC cluster cases, as produced by the bilingual Javanese/Indonesian speakers

For Speaker CJ_f7, the F0 values of vowels following voiceless stops are greater than those following “voiced” stops, at all three points in the vowel measured, and in both the intervocalic and NC cluster cases. The range of differences, between 3-5 Hz, is small for the intervocalic cases and relatively greater for the NC cluster cases, between 12-15 Hz. The F0 value differences are not statistically significant for either case.

For Speaker CJ_m6, the F0 values of vowels in the intervocalic cases do not show a systematic pattern in that they are greater for vowels following the voiceless stops at the 30% point, but smaller otherwise, as compared to those following the “voiced” stops. In the NC cluster cases, the F0 values are greater for vowels following the voiceless stops than for those following the “voiced” stops. The range of differences is actually very small, between 2-4 Hz. Statistically, these differences are not significant.

For Speaker CJ_m7, the F0 values in the intervocalic cases are smaller for vowels following the voiceless stops than for those following the “voiced” stops. This is contrary to what is predicted for voiced vs. voiceless stops or for breathy vs. clear ones. For the NC cluster cases, the F0 values are greater for vowels following the voiceless stops than for vowels following the “voiced” stops. The differences between the voiceless vs. the “voiced” cases are small, ranging between 1-5 Hz, and statistically they are not significant.

The results reported here show that F0 values are consistently lower for vowels following the intervocalic “voiced” stops for only one of the three speakers (i.e. Speaker CJ_f7). Recall that Speaker CJ_f7 is a native speaker of Javanese, and that for the bilingual speakers, the Indonesian "voiced" stops are acoustically realized as voiceless, as shown earlier in Figure 4.13. Consequently, the F0 lowering for Speaker CJ_f7 could not result from the different voicing of the stops. The Indonesian stops in her speech may reflect the Javanese pattern where stops are breathy or clear, in which case the F0 lowering here is due to the breathy quality of the stops. It is conceivable that Speaker CJ_f7 picked up on the F0 difference found in Indonesian, but not the voicing contrast. For the other two speakers, CJ_m6 and CJ_m7, there is practically no systematic pattern in F0 difference for the "voiced" vs. voiceless Indonesian stops.

In the NC cluster cases, vowels following the "voiced" stops have lower F0 than in vowels following the voiceless ones for all three speakers. As shown earlier in Figures 4.20 and 4.21, while intervocalic "voiced" stops are acoustically voiceless, in NC clusters, these stops are acoustically realized as voiced for these bilingual speakers. The difference in voicing may play a role in the different acoustic patterning shown in Figure 4.22. Voiced stops are known to lower F0 of the following vowels (e.g. Lehiste and Peterson, 1961; Hombert, 1978). One may argue that, for Speaker CJ_f7, the greater F0 lowering of vowels following these stops in the NC cluster cases, as compared to those in the intervocalic cases, may result from the voicing contrast. Similarly for the male speakers, the F0 lowering of vowels following the "voiced" stops in the NC cluster cases may come from the voicing effect, even though the differences are quite small.

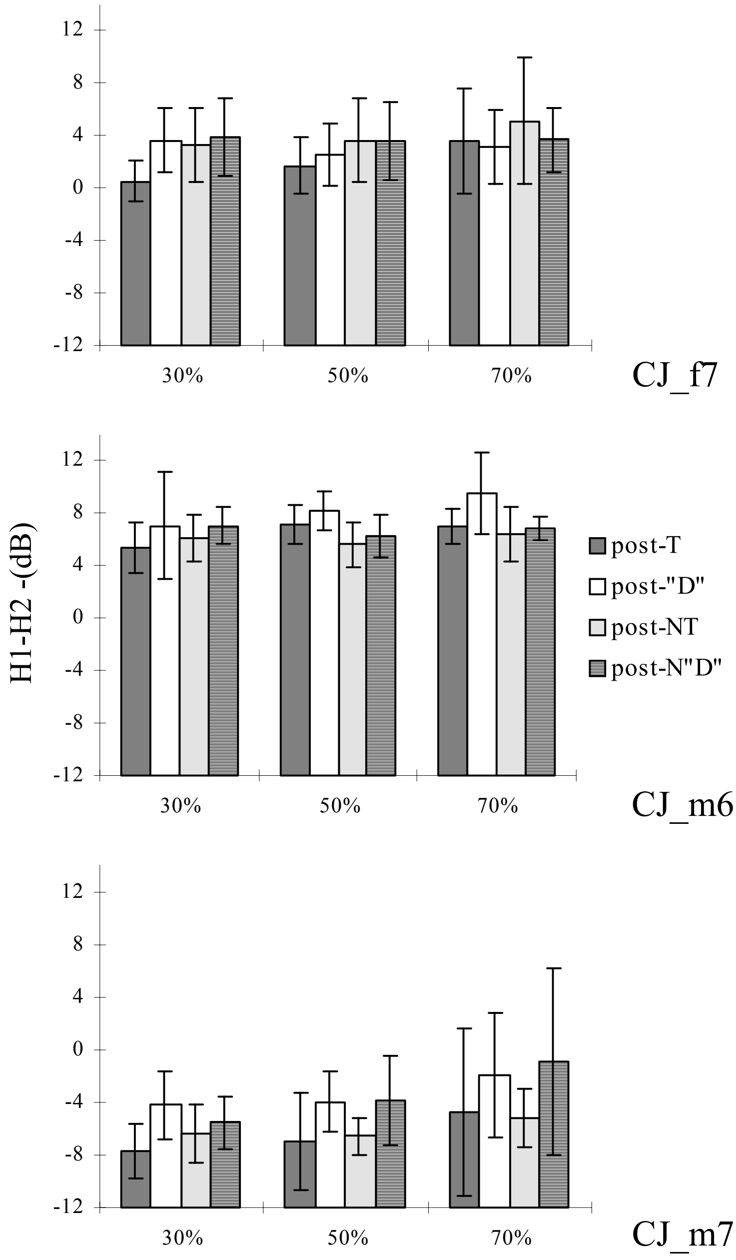


Figure 4.23: Mean H1-H2 values (in dB) for Indonesian vowels following voiceless (T, NT) vs. "voiced" ("D", N"D") stops, in the intervocalic and NC cluster cases, as produced by the bilingual Javanese/Indonesian speakers

I turn now to the acoustic measurements of spectral tilt whereby the amplitude values of the vowel first harmonic are compared with those of the vowel second harmonic (H1-H2). A breathy vowel would have a greater H1-H2 value than a non-breathy one. The results are presented in Figure 4.23.

For Speaker CJ_f7, the mean H1-H2 value is greatest for vowels in the post-“D” cases at the 30% point. At the 70% point, this value is greater for vowels in the post-T cases, contrary to the expected pattern. For the NC cluster cases, this value is greater for vowels in the post-NT cases at the 30% point, no difference at the 50% point for the post-NT vs. post-N”D”, and smaller in the post-N”D” cases at the 70% point. Statistically, the differences in the intervocalic cases at the 30% and 50% points are not significant. These results suggest that, for this speaker, the contrastive stops affect the H1-H2 mean values at points nearer to the release of the stops.

For Speaker CJ_m6, the H1-H2 values are greater for vowels following “voiced” stops than following voiceless stops, at all points and in both the intervocalic and NC cluster cases. The range of differences is between 1-2 dB in the intervocalic cases, and around 1 dB for the NC cluster cases. These differences, while in the expected direction, are quite small and are not statistically significant.

Speaker CJ_m7’s productions displays a pattern similar to Speaker CJ_m6’s productions, in that the H1-H2 values are greater for vowels following “voiced” stops than for vowels following voiceless stops, at all points and in both the intervocalic and NC cluster cases. The range of differences is around 3 dB in the intervocalic cases, and between 1-4 dB in the NC cluster cases. These differences are not statistically significant.

The results provided in Figure 4.23 suggest that Indonesian "voiced" stops, whether realized as voiceless intervocalically or voiced in NC clusters, are to some degree breathy as well (as far as H1-H2 values are concerned), for the bilingual speakers.

Next, I present the acoustic measurements of F3 amplitude, being compared with the amplitude of the first harmonic. If the vowels following the "voiced" stops bear the breathy effect, their H1-A3 values would be greater than when they follow the voiceless stops. The results are shown in Figure 4.24.

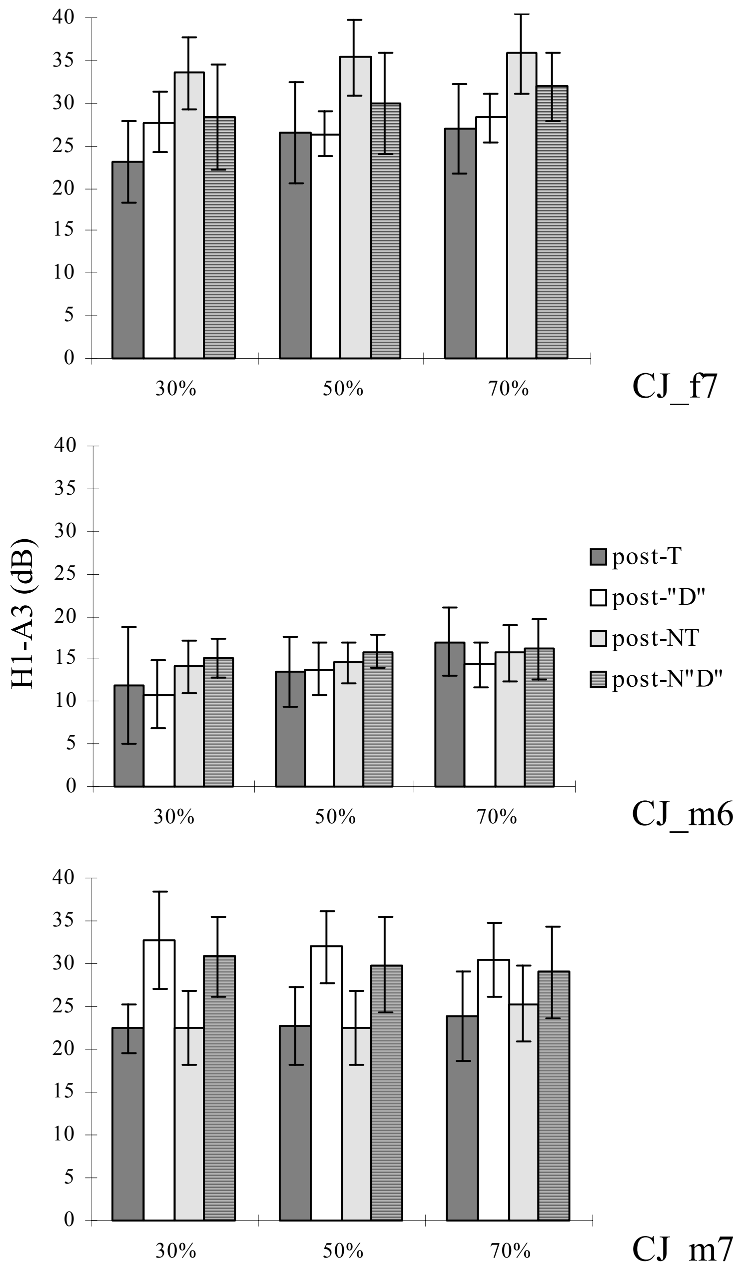


Figure 4.24: Mean H1-A3 values (in dB) of Indonesian vowels following voiceless (T, NT) vs. "voiced" ("D", N"D") stops, in the intervocalic and NC cluster cases, as produced by the Javanese/Indonesian bilingual speakers

For Speaker CJ_f7, the H1-A3 values are greater for vowels following the "voiced" stops than for vowels following the voiceless stops at the 30% and 70% points, with the differences of 5 dB at the 30% point, 0 dB at the 50% point, and 1 dB at the 70% point. However, the reverse is the case for the intervocalic case at the 50% point and the NC cluster cases at all targeted points. This would suggest that if this particular acoustic measure is an indicator of relative breathiness for this speaker, it only occurs at the point closer to the stop release and only when the stop is intervocalic. It seems more likely that this is a weak indicator or perhaps is altogether not an indicator of breathiness for this bilingual speaker, when she speaks Indonesian.

Contrary to Speaker CJ_f7, the H1-A3 values for Speaker CJ_m6 are greater for vowels in the post-"D" case at the 50% point and for those in the post-N"D" cases at all three points, as compared to their respective voiceless counterparts. The differences (of 1 dB at the most) are quite small and are not statistically significant. This result suggests that this acoustic measure, if it functions as an indicator of relative breathiness for this speaker when speaking Indonesian, is a weak one.

In contrast to the two other speakers, for Speaker CJ_m7 the acoustic measure of H1-A3 positively indicates the breathy vs. non-breathy voice quality for the Indonesian stops. In both the intervocalic and the NC cluster cases, the H1-A3 values for vowels are greater following the "voiced" stops than following the voiceless ones. For the intervocalic cases, the range of the H1-A3 values is between 24 to 33 dB; for the NC cluster cases, it is between 25-31 dB. The differences of these values for the post-T vs. post-"D" vowels are in the range of 6 to

11 dB, and for the post-NT vs. post-N“D” vowels they are in the range of 4 to 9 dB. These differences are quite large and statistically significant ($p < .05$) for all, except for the NC cluster case at 70% point. This suggests that the acoustic measure of the F3 amplitude is reliable to distinguish the two stop series in the Indonesian of Speaker CJ_m7.

The next measurement I present is H1-A1, an acoustic measure of F1 bandwidth (Hanson, 1997). The results are shown in Figure 4.25.

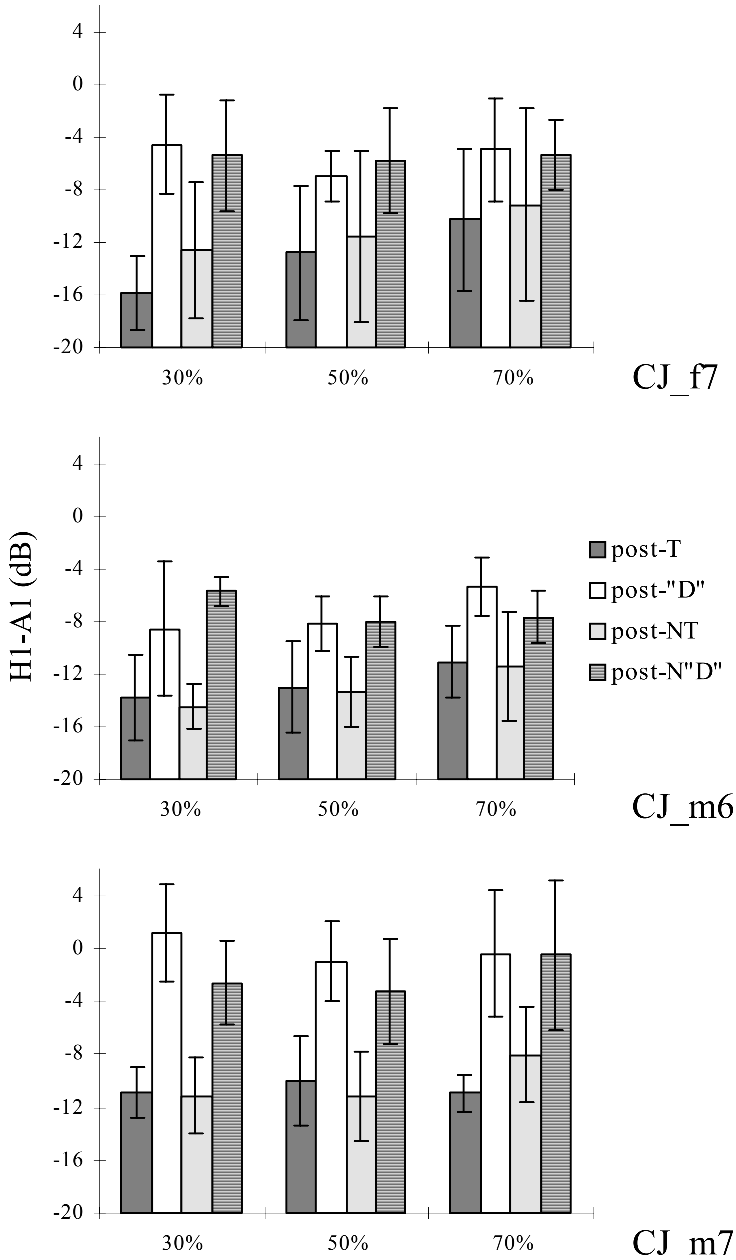


Figure 4.25: Mean H1-A1 values (in dB) of Indonesian vowels following voiceless (T, NT) vs. "voiced" ("D", N"D") stops, in the intervocalic and NC cluster cases, as produced by the Javanese/Indonesian bilingual speakers

For Speaker CJ_f7, the H1-A1 values are greater for the post-“D” and the post-N“D” vowels, as compared to the post-T and the post-NT ones, at all three target points. The ranges of these values are between -16 to -4 dB in the intervocalic cases, and between -13 to -5 dB in the NC cluster ones. The H1-A1 value differences range between 5-11 dB for vowels in post-T vs. post-“D” cases and between 4-8 Hz for those in post-NT vs. post-N“D” ones. Statistically, these differences are significant ($p < .05$) for the intervocalic and NC cluster cases at the 30% point.

Speaker CJ_m6 shows a pattern similar to that of Speaker CJ_f7. The H1-A1 values are greater for the post-“D” and the post-N“D” vowels, as compared to the post-T and the post-NT ones, at all three target points. The ranges of these values are between -14 to -5 dB for the intervocalic cases, and between -14 to -6 dB for the NC cluster ones. In the intervocalic cases, the range of differences for vowels in post-T vs. post-“D” cases is between 5-6 Hz. For those in post-NT vs. post-N”D” cases, it is between 4-9 Hz. These differences are statistically significant ($p < .05$) for the intervocalic cases at all three points and for the NC cluster cases at the 30% and 50% points.

Speaker CJ_m7 also shows a pattern similar to Speakers CJ_f7 and CJ_m6, with the H1-A1 values being greater for the vowels following the “voiced” stops than following the voiceless ones, at all three target points and in both the intervocalic and the NC cluster cases. The ranges of these values are between -11 to 1 dB for both the intervocalic and the NC cluster cases. The H1-A1 value differences range between 9-12 dB for the post-T vs. post-“D” vowels and between 7-8 dB for the post-NT vs. post-N“D” ones. Statistical analysis indicates that these differences are significant ($p < .05$) for both the intervocalic and NC cluster cases, at all points.

Overall, all three speakers show a strong tendency where the H1-A1 values are greater for vowels following the Indonesian “voiced” stops, indicating that these vowels have relatively broader first formant bandwidth. Recall that these stops are acoustically voiceless in the intervocalic position. Given the fact that these speakers are bilingual Javanese/Indonesian, the broad bandwidth of these vowels arguably results from the effect of breathiness due to transfer from Javanese.

I turn now to the HNR measurements of noise, of the whole duration of the target vowel. If the Indonesian “voiced” stops are breathy for the bilingual Javanese/Indonesian speakers, we predict to see greater HNR values for vowels following the Indonesian “voiced” stops than for vowels following the voiceless stops. The results are presented in Figure 4.26.

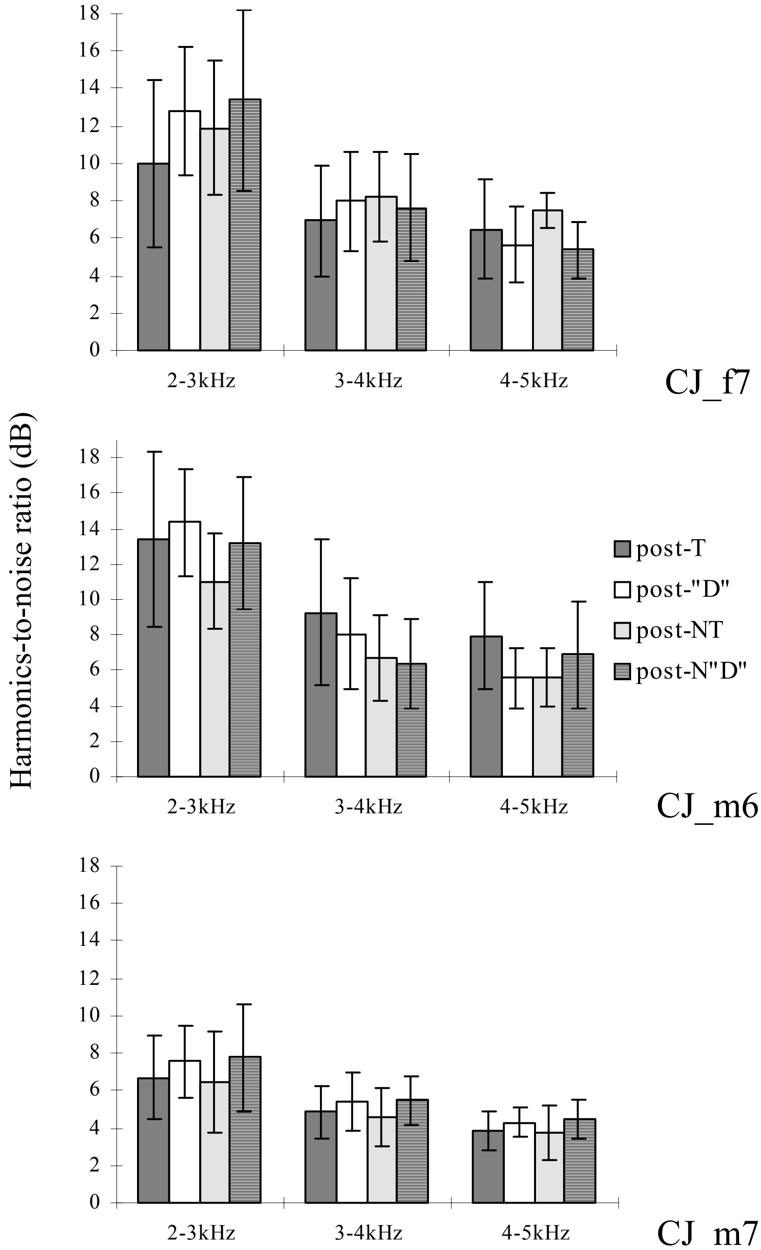


Figure 4.26: Mean harmonics-to-noise ratio (HNR) values (in dB) of Indonesian vowels following voiceless (T, NT) vs. "voiced" ("D", N"D") stops, in the intervocalic and NC cluster cases, as produced by the Javanese/Indonesian bilingual speakers

For Speaker CJ_f7, the HNR values are lower for vowels in the post-“D” cases than in the post-T ones, in the frequency range of 3-5 kHz. In the NC cluster cases, the HNR values for vowels are lower for the post-N“D” than for the post-NT cases within the frequency range of 4-5 kHz. The difference is at the most 2 dB. These value differences are statistically significant ($p < .05$) only for vowels in the NC case within the 4-5 kHz frequency range.

For Speaker CJ_m6, the HNR values are lower for vowels in the post-“D” vs. the post-T cases within the frequency range of 3-5 kHz, and for vowels in the post-N“D” vs. the post-NT cases within the 3-4 kHz range. The difference is at the most 2 dB. These differences are not statistically significant.

For Speaker CJ_m7, the HNR values for the post-“D” and the post-N“D” vowels are consistently greater than for the post-T and the post-NT ones, at all the targeted frequency ranges. This implies that noise does not play a role in distinguishing the two stop series in Indonesian with respect to breathiness for this speaker.

The summary of the results discussed in this section is presented in Table 4.5. The shaded boxes are those where either there is no consistent pattern, or where the results indicate the opposite of the expected tendency in a breathy/clear contrast.

Table 4.5: Summary of the acoustic measurements of Indonesian vowels following “voiced” vs. voiceless stops for the bilingual speakers

	CJ_f7	CJ_m6	CJ_m7
F0	T > “D” NT > N”D”	no pattern NT > N“D”	T < “D” NT > N“D”
H1-H2	no pattern	T < “D” NT < N“D”	T < “D” NT < N“D”
H1-A3	T </≈ “D” NT > N“D”	T >/≈ “D” NT ≈ N“D”	T < “D” NT < N“D”
H1-A1	T < “D” NT < N“D”	T < “D” NT < N“D”	T < “D” NT < N“D”
HNR	T > “D”[1] NT > N“D”	T > “D”[2] NT > N“D”	T < “D” NT < N“D”

Note:
[1]in the 4-5kHz range in the intervocalic cases and in the 3-5 kHz range in the NC cases
[2]in the 3-5 kHz range in the intervocalic cases and in the 3-4 kHz range in the NC cases

In summary, the pattern of F0 for vowels following the stops here shows that speakers may vary with respect to F0 lowering. As discussed earlier, only one of the three speakers actually shows F0 lowering for the intervocalic cases, and Indonesian “voiced” stops are acoustically realized as voiceless for the bilingual Javanese/Indonesian speakers. I argue that the F0 lowering for this speaker is due to breathiness realized in the vowel following the stops. In NC cluster cases, however, all three speakers show F0 lowering, which seems to be due to the acoustically voiced stops following the homorganic nasal.

With respect to the spectral tilt measurements (H1-H2 and H1-A3), vowels following “voiced” stops display a steeper tilt than following a voiceless stop in both the intervocalic and NC cluster cases, for one of the three speakers, i.e. Speaker CJ_m7. For another speaker, i.e. Speaker CJ_m6, this is the case only in the lower frequencies (H1-H2). If the spectral tilt is a correlate of breathiness of the Indonesian "voiced" stops for the bilingual speakers, the results here show that speakers may vary in whether the effect of breathiness on spectral energy is realized in the lower and/or high spectral frequencies, and speakers may vary in the degree of transference of breathiness from Javanese to Indonesian.

For all three speakers, the H1-A1 value indicates that the distinction of "voiced" vs. voiceless stops is acoustically realized with the "voiced" stop cases showing greater H1-A1 value as compared to the voiceless ones. Consequently, vowels following the Indonesian "voiced" stops tend to display wider F1 bandwidth measured by H1-A1, for the bilingual speakers. Recall that this is also the case for the monolingual Indonesian speakers, as shown previously in Table 4.3. The difference between the monolingual and the bilingual speakers is that for the monolingual speakers, the intervocalic voiced stops are produced with vocal fold vibration; while for the bilingual speakers, these stops are produced with no vocal fold vibration. Thus, the wider F1 bandwidth for the monolingual speakers and that for the bilingual speakers may result from different sources.

In the next section, I compare the similarities and differences of the acoustic cues that the bilingual speakers use in their productions of the Indonesian and Javanese stops. I also discuss the overall acoustic findings of these stops as realized on the following vowel, using the acoustic measures of relative breathiness.

4.8 Discussion

There are two issues that I discuss in this section. First, I discuss the relation between F0 lowering and F1 bandwidth widening with the articulation of breathy and modal voices. Second, I compare the acoustic characteristics of vowels following the Indonesian “voiced” stops and the Javanese breathy stops by the bilingual Javanese/Indonesian speakers.

With respect to the Indonesian stops in the speech of the monolinguals vs. the bilinguals from Java, the main overall difference seems to lie in the status of voicing and the effect of F0. For the monolingual speakers, Indonesian voiced stops in the intervocalic position are acoustically voiced; for the bilingual speakers, they are voiceless. Note that in the NC cluster cases, they are also realized as voiced for the bilingual speakers. For the monolingual speakers, the effect of stop voicing is realized as the lowering of F0, in both the intervocalic and NC cluster cases. For the bilingual speakers, only one of the speakers shows F0 lowering in the intervocalic cases, which I argue to be due to the influence of the Javanese pattern, i.e. breathiness, rather than due to voicing. In the NC cluster cases, these stops show the F0 lowering effect for all three speakers.

The pattern of voicing and F0 lowering for the bilingual speakers in Indonesian is consistent with the pattern they show for the stops in Javanese. The intervocalic non-modal stops in Javanese are realized as acoustically voiceless, and the speaker who shows the F0 lowering of intervocalic “voiced” stops in Indonesian also shows F0 lowering of intervocalic breathy stops in Javanese. No F0 lowering occurs for the other two speakers for both the Indonesian and Javanese cases. The non-modal stops in NC clusters are realized as voiced in Javanese, and all three speakers' productions display the effect of F0 lowering.

As I have briefly discussed earlier, both voicing and breathiness of stops cause the F0 of the following vowel to lower. This is due to the way voicing and breathiness are produced. Both phonation types involve incomplete closure of the vocal folds. Henton et al. (1992) describe voicing and breathiness as part of a continuum with respect to the state of the glottis, in that breathy voice is produced with a greater degree of glottal opening as compared to modal voice. The greater degree of glottal opening also results in other acoustic characteristics that would distinguish the two phonation types, such as a greater degree of additive noise for breathy voice due to the greater rate of airflow, a greater degree of harmonic dampening for breathy voice due to a greater degree of energy loss, etc.

It is interesting that the results in this study show that both voicing and breathiness of stops affect the F1 bandwidth of the following vowel. The findings suggest that vowel F1 bandwidth tends to be greater when the preceding stop is either a voiced modal stop (e.g. in the Indonesian of the monolingual speakers) or a voiceless breathy stop (e.g. in the Indonesian and Javanese of the bilingual Javanese/Indonesian speakers), as compared to a voiceless modal stop. This may be a phenomenon parallel to that of F0 lowering. Formant bandwidths tend to be wider whenever there is a certain degree of opening (or abduction) of the glottis, especially that which precipitates the loss of airflow and the loss of acoustic energy at low frequencies (House and Stevens, 1956; Hanson, 1997). I have found no acoustic studies in which voiced vs. voiceless stops are compared in their effect to F1 bandwidth of the following vowel.

I turn now to the discussion of the acoustic characteristics of vowels following the Indonesian and the Javanese stops by the bilingual speakers, with respect to relative breathiness measures. In Table 4.6, I present a summary of comparison for these speakers.

Table 4.6: Comparison of the acoustic characteristics of vowels following the contrastive stops in Indonesian and Javanese by the bilingual speakers

		CJ_f7	CJ_m6	CJ_m7
F0:	I[1]	yes	no	no
	J[2]	yes	no	no
H1-H2:	I	no	yes	yes
	J	no	yes	yes
H1-A3:	I	perhaps	no	yes
	J	yes	perhaps	yes
H1-A1:	I	yes	yes	yes
	J	yes	yes	yes
HNR:	I	yes	yes	no
	J	yes	yes	no

Note:
[1]Indonesian
[2]Javanese

"Yes" in these cells indicates that the results agree with the expected acoustic pattern for breathiness, e.g. vowels following breathy stops would have lower F0 than following modal ones; "no" indicates that either the results disagree with the expected pattern or they show no systematic pattern. No systematic pattern means that the results may show a combination of at least two of the three possible results: agreement with the pattern, opposite the pattern, and no difference between post-breathy vs. post-modal cases. “Perhaps” indicates that the results are mixed in that they may essentially be “yes” but the difference is very small, or they may be “yes” for the intervocalic cases but they may show no systematic pattern for the NC cluster cases, or they may be “yes” for the intervocalic cases but “no” for the NC cluster cases. A box surrounded by thick lines indicates different results for Indonesian vowels vs. for Javanese vowels for a particular speaker.

First, it is interesting to note how consistent each speaker is across languages. The results for Speaker CJ_m7 are clearest, with the acoustic pattern of vowels following the Indonesian “voiced” stops matching to that of vowels following the Javanese breathy stops. This suggests that, at least for some speakers, the acoustic pattern of breathiness in Javanese is manifested in Indonesian. However, some other speakers may use different acoustic patterns for vowels following the Indonesian “voiced” stops than for vowels following the Javanese breathy stops, as exhibited by the results for Speakers CJ_f7 and CJ_m6. For these two speakers, the acoustic differences of vowels following the Indonesian “voiced” stops vs. following the Javanese breathy stops are reflected in the spectral tilt at high frequencies. For Speaker CJ_f7, the spectral tilt for vowels following the Javanese breathy stops display the acoustic pattern of breathiness; however, the spectral tilt in this speaker’s productions of vowels following the Indonesian “voiced” stops do not positively mirror those in Javanese. For Speaker CJ_m6, the spectral tilt for vowels following the Javanese breathy stops exhibits no systematic pattern for breathiness in the intervocalic cases, but it does in the NC cluster cases. Overall, these differences suggest that they may modify or adjust their method of phonating to accommodate the differences between the modal voice in Indonesian and the breathy voice in Javanese.

A perception study comparing the Javanese breathy stops vs. Indonesian "voiced" stops as produced by these bilingual speakers may provide insight to the possible different degrees of breathiness of these stops. However, one should consider the possibility that the language background of potential listeners may affect which acoustic cues that they are sensitive to, with respect to the perception of breathiness. In a synthesis experiment, Bickley (1982) finds that Gujarati listeners are sensitive to spectral tilt differences, but not to an increase in noise, in judging the degree of breathiness. On the other hand, Ladefoged and Antoñanzas-Barroso (1985) and Klatt and Klatt (1990) find that American English listeners are sensitive to both of these acoustic cues. Note that breathiness in Gujarati is phonemic and it is not in American English. It is possible that listeners are sensitive to different acoustic cues, depending on (though perhaps not entirely) whether breathiness is phonemic or not in their primary language.

With respect to the glottal configuration for breathy vs. modal vowels, the most common description for the production of these vowels refers whether or not there is an opening of the vocal folds at the posterior end, due to the pull of the arytenoid cartilages (Lieberman and Blumstein, 1993; Hanson, 1997; Stevens 2000; Ladefoged 2001, among others). For Javanese, Hayward (1993) finds that a breathy voice quality can be produced without the opening at the posterior end, but with the vocal cords that are generally more open (as opposed to more close and slightly bowed for the modal voiceless stops); or with the glottal chink combined with the vocal folds that are more down and apart. These different manners in which breathiness is produced could result in different acoustic manifestations. One may suggest that the different combinations of acoustic measures of the individual speakers shown in Table 4.6 are due to the differences in the production of the breathy vs. modal contrast. There may be several ways in which vowels differ in their F0, such as the tension of the vocal folds and the height of the larynx (see Ohala, 1978 for detailed discussion regarding the sources of F0 variation). Hayward's (1995) observation, based on fibreoptic laryngoscopy, suggests that a Javanese speaker may vertically lower the larynx during the closure of a breathy stop. To account for the differences in F0 patterning among the three speakers in the present study, it is possible that Speaker CJ_f7 who shows the pattern of F0 lowering for vowels following breathy stops may either vertically lower her larynx and/or vary the tension of her vocal folds, while the other two speakers may not.

With respect to the speakers' differences in spectral tilt, F1 bandwidth, and additive noise, it may be the case that each speaker uses certain glottal adjustment that facilitates or inhibits certain acoustic effects shown by the results. For example, Speaker CJ_m7 may produce breathiness without the glottal chink, which may account for the fact that, for this speaker, vowels following breathy stops do not display higher energy noise, as compared to the energy of harmonics.

In Chapter 6 (Conclusion), I further discuss issues that need to be addressed in future studies on breathiness, including perceptual studies, articulatory studies, and studies on the effect of speakers' gender on breathiness. In the next chapter, I turn to the discussion of the syllabification status of the homorganic nasal in root-medial NC clusters, comparing Indonesian and Javanese. The acoustic analyses are based on the measurements of the durations of vowels preceding the NC clusters and the durations of the NC clusters themselves, and the measurements of H1-A1 values as a correlate of vowel F1 bandwidth.

CHAPTER FIVE:
SYLLABIFICATION OF NASAL + STOP CLUSTERS IN INDONESIAN AND JAVANESE

In this chapter, the focus of analysis is the syllabification of homorganic nasal stop clusters in root-medial position, such as the velar nasal and stop in [taŋga] 'stairs' in Indonesian and [rɔŋgʱɔ] 'noble' in Javanese. In most of the literature, it has been assumed that in Indonesian these root-medial clusters are heterosyllabic, in that the nasal is in coda of the previous syllable, while the following stop is in onset of the following syllable (e.g. Lapoliwa, 1981). In Javanese, however, there is disagreement as to how such clusters are syllabified, i.e. whether they are heterosyllabic (e.g. Yallop, 1982) or tautosyllabic with both nasal and stop in the onset (e.g. Robson, 1992; Benua, 1996).

Here, the discussion of the syllabification of these medial clusters in Javanese and Indonesian is based on their phonological patterns and acoustic analysis. Throughout the chapter, I will refer to the nasal + stop clusters as NC clusters. I investigate the syllabification of these clusters in Indonesian in the speech of the bilingual Central Javanese/ Indonesian speakers. If the Javanese clusters are tautosyllabic, we can investigate the question of whether in the Indonesian of the Central Javanese speakers, they adopt the expected Indonesian pattern, or whether the structure of the Javanese system influences their production. In the present study, I focus on Javanese speakers from Central Java, assuming that Central and Eastern dialects of Javanese would be similar with respect to the syllabification of NC clusters. However, an acoustic study in the future would be needed to verify whether this is the case.

Another issue that I discuss here is whether segments that are tautosyllabic in onset position form a complex unit or whether they function as a sequence of two segments. When NC clusters are tautosyllabic and can occur in onset position, they are usually assumed to form a complex segment, namely a prenasalized stop. Herbert (1986) argues that the duration of nasal + stop sequences behaving as single segments would be equivalent to that of single consonants. Were they clusters, the NCs would be in violation of the sonority sequencing principle (e.g. Clements, 1990; Zec, 1995). However, their status of being a unit would exclude them from the sequencing principle. Based on UPSID, Maddieson and Ladefoged (1993) state that 12 % of the world's languages have a series of 4 or 5 prenasalized stops (usually paralleling the place of articulation of the stop series). If these structures behave as a complex unit, we would predict that their timing pattern would be similar to other non-complex units. This is what has been found in Fijian (Maddieson, 1989). If, however, the NC cluster is a sequence, then its acoustic duration would be comparable to that of the other clusters in this position.

The organization of this chapter is as follows. In § 5.1, I discuss the occurrence and patterns of NC clusters in Indonesian and Javanese; then in § 5.2, I review studies on NC clusters in other languages. In § 5.3, methods particularly relevant to the study not discussed in Chapter 2 are presented. In § 5.4, I present the acoustic results and their analysis, and the discussion in § 5.5.

5.1 Nasal + stop clusters (NC) in Indonesian and Javanese

This section is divided into two subsections. In § 5.1.1 I present the Javanese consonants and NC clusters. In § 5.1.2 I discuss the distribution of the Indonesian consonants in general and the NC clusters in particular. In both languages, a nasal and a stop may be adjacent in root internal position. They may also become adjacent due to affixation. Both of these cases are presented and illustrated.

5.1.1 Consonants and NC clusters in Javanese

Before discussing the distribution of Javanese consonants, I discuss first the characteristics of roots in this language. The majority of the indigenous roots in Javanese are bisyllabic, and in most cases the shape of the root is (C)CV(N)(C)(C)V(C) (e.g. Uhlenbeck, 1978). When two Cs occur in the root-initial position, they may consist of an obstruent (stop, affricate or fricative) followed by a liquid, as shown in (1). Consonant clusters of this type are actually quite common in Javanese.

(1)	[p$^{\text{ɦ}}$lɔnǰ$^{\text{ɦ}}$ɔ]	‘shop’	[trasi]	‘shrimp paste’
	[čluri̇t]	‘sickel’	[srawʊŋ]	‘mingle’
	[klɔsɔ]	‘mat’	[krikɪl]	‘pebble’

The stop + liquid sequences also occur commonly in root-medial position, as shown below.

(2)	[k$^{\text{ɦ}}$əp$^{\text{ɦ}}$lak]	‘fall backward’	[səp$^{\text{ɦ}}$raŋ]	‘across’
	[ič$^{\text{ɦ}}$lik]	‘walk fast’	[sik$^{\text{ɦ}}$raʔ]	‘hair parting’

A maximum of three consonants can occur in root-medial position. In this case, the first C is a homorganic nasal, followed by a stop (either clear or breathy). The third C is a liquid. This is exemplified in (3).

(3)				
	[tumplək]	'turn upside down'	[ambʱrɔl]	'fall apart'
	[ančlap]	'attack'	[munčrat]	'splash'
	[aŋgʱlɔŋ]	'relieved'	[čʱaŋkrɪʔ]	'grasshopper'

Word- or root-finally, only single consonants may occur, and there are no final NC's.

In this study, I focus on the occurrence of adjacent nasals and stops. These two consonants may be adjacent in root-medial position, and they may become adjacent at the edges of a root due to affixation. The set of examples in (4) shows the cases of root-medial homorganic nasals preceding breathy and clear stops in Javanese roots. Note that breathy stops are acoustically voiceless in the intervocalic position, but are voiced in NC clusters, as I have shown in Chapter 4.

(4) *Root-medial nasal and stop clusters in Javanese*

(a) breathy stops		(b) clear stops	
[tambʱa]	'cure'	[tampa]	'receive'
[pʱandʱəŋ]	'k.o. fish'	[pʱantər]	'loud'
[kʱunḍʱu]	'marble'	[munṭu]	'cooking utensil'
[lɔnǰʱɔŋ]	'oval'	[mɔnčɔŋ]	'snout'
[rɔŋgʱɔ]	'a Javanese title'	[rɔŋkɔ]	'skeleton'

The nasals in these cases agree in place of articulation with the following stop. In addition to the type of NC clusters described above, a nasal may also be adjacent to a fricative in root-medial position. The set of examples in (5) illustrates this.

(5) *Velar nasal + fricative cluster in Javanese*

/liŋsa/	→	[liŋsɔ]	'louse'
/luŋsur/	→	[luŋsʊr]	'pass down'
/maŋsa/	→	[mɔŋsɔ]	'victim'

This consonant cluster is such that the nasal is always velar, thus not homorganic, and the following consonant is always the fricative /s/. The occurrence of this type of cluster in root-medial position in Javanese has several historical origins. Some of the Javanese words with /ŋs/ cluster are of Sanskrit (Skt) origin, e.g. /baŋsa/ from Skt /vaMsa/ 'clan' (where M indicates anusvara). Some other Javanese words with /ŋs/ cluster are of Proto-Austronesian (PAN) origin (Wolff, p.c.), e.g. /suŋsuŋ/ from PAN /čuŋčuŋ/ 'go to meet, go against wind'. This form may have been the result of reduplication of the monosyllabic PAN root /čuŋ/. Cases like /luŋsur/ 'pass down', which also has an alternate form /lusur/, have been claimed as an instance of medial nasal accretion (or nasal insertion) that happens sporadically in many Western Indonesian languages, resulting in the root medial cluster of velar nasal + fricative (Wolff, p.c.). The /ŋs/ clusters in root medial position also occur in Indonesian, and may have similar historical origins as they do in Javanese. Given its unusual (historical) properties, the root-medial /ŋs/ cluster in Javanese is excluded from the discussion at present.

The occurrence of word-initial NC clusters in Javanese is the result of attaching the homorganic nasal prefix *N*- to a root. This is exemplified in (6). In these examples, the nasal prefix functions as a verbal prefix.

(6) *Prefix nasal + breathy stop in root-initial position in Javanese*

/*N*- + p$^{\text{ɦ}}$alaŋ/	→ [mb$^{\text{ɦ}}$alaŋ]	'throw'
/*N*- + t$^{\text{ɦ}}$ulaŋ/	→ [nd$^{\text{ɦ}}$ulaŋ]	'feed'
/*N*- + ʈ$^{\text{ɦ}}$isiʔ + i/	→ [nɖ$^{\text{ɦ}}$isiʔi]	'pass'
/*N*- + č$^{\text{ɦ}}$ak$^{\text{ɦ}}$oŋ/	→ [ňǰ$^{\text{ɦ}}$ak$^{\text{ɦ}}$ɔŋ]	'chat'
/*N*- + k$^{\text{ɦ}}$eret/	→ [ŋg$^{\text{ɦ}}$ɛrɛt]	'drag'

As shown here, the prefix nasal takes on the place of articulation of the following root-initial breathy stop. Like those in root medial position, root-initial breathy stops are acoustically voiced when they immediately follow the verbal nasal prefix *N*-, as shown in (6).

When the root-initial stop is clear or modal, the nasal of the prefix assimilates its place of articulation to that of the root-initial stop and the stop itself is deleted; or coalescence takes place, as shown in (7).

(7) *Prefix nasal + clear stops and fricative in root-initial position in Javanese*

/*N*- + paro/	→	[maro]	'halve'
/*N*- + tuku/	→	[nuku]	'buy'
/*N*- + ʈoʈok/	→	[nɔʈɔʔ]	'knock'
/*N*- + sɛrɛt/	→	[ɲɛrɛt]	'drag'
/*N*- + čoloŋ/	→	[ɲɔlɔŋ]	'steal'
/*N*- + kukur/	→	[ŋukʊr]	'scratch'

The same phenomenon also occurs when the root-initial consonant of the root is the voiceless fricative /s/; the prefix *N*- is realized as palatal. The contrast between the underlying alveolar and retroflex is neutralized in the coalesced nasal.

There are also cases where the prefix nasal precedes a sonorant. This is shown in (8).

(8) *Prefix nasal + sonorant in root-initial position in Javanese*[10]

/*N*- + rampʊŋ + ke/	→	[ŋᵊrampʊŋke]	'finish'
/*N*- + luŋkʱuh + i/	→	[ŋᵊluŋgʱuʷi]	'sit on'
/*N*- + watʱul + ke/	→	[matʱʊlke]	'tell on somebody'
/*N*- + jakin + i/	→	[ŋᵊjakini]	'believe'

When the root-initial consonant is a liquid, the prefix nasal is realized as velar. Impressionistically, a brief schwa separates the two consonants when both of them surface. Adjacent nasal prefix and a root-initial labio-velar glide coalesce resulting in a bilabial nasal. However, when the root begins with the palatal glide, the prefix nasal is realized as velar with a brief schwa.

Nasals may also occur root-finally in Javanese. In this position, there is a three way place contrast: [m, n, ŋ]. These nasals are specified for place of articulation. Some examples of the occurrence of adjacent nasal-stop and nasal-nasal in the root-suffix boundary are shown in (9).

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[10] The data given here are from the Central dialect of Javanese. There are cases where the Eastern and the Central dialects differ in their vocabulary and suffixes. For example, the word for 'finish' in the Eastern dialect is /mari/ and the equivalent suffix of /ke/ is /nɔ/, and thus the equivalent form for 'finish' is [marɛʔnɔ], and for 'tell on somebody' is [matʱʊlnɔ].

The suffix *-ke* indicates that there is a benefactive object, and the suffix *-mu* is the second person possessive clitic.

(9) *Adjacent nasal-stop and nasal-nasal in the root + suffix boundary in Javanese*

(a) Nasal + voiceless stop

/*N*- + sulam + ke/	→	[ɲulamke]	'sew'
/*N*- + salin + ke/	→	[ɲalɪnke]	'change'
/*N*- + sənəŋ + ke/	→	[ɲənəŋke]	'please'

(b) Nasal + nasal

/garəm + mu/	→	[garəmmu]	'your salt'
/ləŋən + mu/	→	[ləŋənmu]	'your arm'
/sulɪŋ + mu/	→	[sulɪŋmu]	'your flute'

When a suffix beginning with a stop follows a root with final nasal, no place assimilation or coalescence takes place. Other consonants may also occur in the root-final position, except for the palatal consonants: / č , $č^{ɦ}$, ɲ /, and the glide. When the following suffix begins with a consonant, both consonants in root-final position and in suffix-initial position surface.

I turn now to the discussion of the syllabification of the NC clusters in Javanese. As mentioned earlier, there is disagreement as to whether these medial clusters are heterosyllabic (e.g. Yallop, 1982) or tautosyllabic (e.g. Robson, 1992; Benua, 1996). The vowel centralization phenomenon (studied in Chapter 3), governed by syllable structure, provides phonological evidence for determining whether the nasal portion of a NC cluster is in onset position or not. The data in (10-13) illustrate this phenomenon. A period after a vowel or a consonant indicates a syllable break, given the vowel alternation. First, I discuss vowel alternation in Javanese CVCV vs. CVCVC words.

(10) *Vowel alternation and syllable structure in Central Javanese*

(a) Penultimate V in CVCV words				(b) Penultimate V in CVCVC words			
/titi/	→	[ti.ti]	'meticulous'	/titip/	→	[ti.tɪp]	'leg'
/kuku/	→	[ku.ku]	'finger'	/kukur/	→	[ku.kʊr]	'scratch'
/tata/	→	[tɔ.tɔ]	'arrange'	/tatap/	→	[ta.tap]	'bump'

As shown in (10a), a non-low vowel in a penultimate and in a final syllable is realized as tense (which I will call *non-centralized* to be consistent with the use of the term in Chapter 3) when the syllable is open. The examples in (10b) show that a non-low vowel in a final closed syllable is realized as lax (or *centralized*). The penultimate vowels are in an open syllable and realized as non-centralized. As discussed in Chapter 3, the low vowel /a/ is realized as [ɔ] in final open syllables, and as [a] in closed ones. In addition, /a/ in penultimate open syllables harmonizes with the one in final syllables: it is realized as [a] when the final vowel in a closed syllable is [a], but as [ɔ] when the final vowel in an open syllable is [ɔ].

Some words in Javanese, especially those that are of Sanskrit or Arabic origin, may have the shape of CVCCV. The question is how the word-medial consonant cluster is syllabified in these words: are they tauto- or heterosyllabic? The data in (11) exemplify this case.

(11) *CVCCV words in Javanese*

/p^{ɦ}ukti/ → [p^{ɦ}ʊk.ti] ‘evidence’ vs. /p^{ɦ}ukit/ → [p^{ɦ}u.kɪt] ‘hill’

/sirna/ → [sɪr.nɔ] ‘disappear’ vs. /siram/ → [si.ram] ‘bathe’

/darma/ → [dar.mɔ] ‘duty’ vs. /damar/ → [da.mar] ‘k.o. tree’

As shown here, the non-low vowels in the penultimate syllable preceding the liquid-fricative and the liquid-nasal clusters are realized as centralized: [p^{ɦ}ʊ̠k.ti], [sɪ̠r.nɔ], in contrast to when they precede a single consonant: [p^{ɦ}u̠.kɪt], [si̠.ram]. The low vowel /a/ in the penultimate syllable is realized as [a] preceding the liquid-nasal cluster. If the liquid in /darma/ were in onset position, we would expect it to surface as *[dɔ.rmɔ], rather than [dar.mɔ]. Thus, the vowel alternation in these examples suggests that the first consonant of the root-medial consonant clusters is in the coda position of the penultimate syllable.

When the root-medial cluster consists of a nasal and a stop, where the nasal agrees in place of articulation with the following stop, we encounter vowel alternation similar to that described in (10). The set of data in (12) illustrates cases with root-medial NC clusters. Note that while these data exemplify the case with velar NC clusters, this pattern also applies to NC clusters with the other places of articulation (i.e. bilabial, dental, retroflex, and palatal).

(12) *Vowel alternation and root-medial NC clusters*

(a) CVNCV

/tiŋk^{ɦ}i/ → [ti.ŋg^{ɦ}i] ‘louse’

/tuŋk^{ɦ}u/ → [tu.ŋg^{ɦ}u] ‘wait’

/raŋka/ → [rɔ.ŋkɔ] ‘skeleton’

(b) CVNCVC

/liŋkʱis/	→ [li.ŋgʱɪs]	'machete'
/muŋkur/	→ [mu.ŋkʊr]	'face down'
/maŋkat/	→ [ma.ŋkat]	'depart'

As shown in (12a), when the final syllable is a CV, the penultimate and the final vowels agree in tenseness or centrality, mirroring the case in CVCV words illustrated in (10a). When the final syllable is a CVC, as shown in (12b), the final non-low vowel is impressionistically centralized and the same vowel in the penultimate syllable remains non-centralized. In the case of /a/, it is realized as [a] in the final syllable, and the penultimate /a/ harmonizes to the same vowel in the final syllable, parallel to the phenomenon illustrated in (10b). The realization of the non-low vowels in the penultimate syllable suggests that the nasal portion of the root-medial NC cluster is not in the coda position. If this nasal were in the coda position, we would expect *[lɪŋgʱɪs] and *[mʊŋkʊr], where both the penultimate and the final vowels are centralized. As seen in Chapter 3, these forms do not occur in Central Javanese. Note, however, that these forms do occur in Eastern Javanese due to vowel harmony. Of course, one might argue that the syllable structure of the medial NC in forms like [lɪŋgʱɪs] and [mʊŋkʊr] is heterosyllabic in Eastern Javanese, in contrast to the Central dialect, and that the surface realization of the vowels is due to either vowel harmony and/or syllable structure. However, this argument would not account for the data of Eastern Javanese, shown in (13).

(13) *Vowel alternation in Eastern Javanese*

/lind̪u/	→	[lind̪u], *[lɪnd̪u]	'earthquake'
/wiŋkɔ/	→	[wiŋkɔ],*[wɪŋkɔ]	'k.o. snack'
/timbɔ/	→	[timbɔ], *[tɪmbɔ]	'bucket'

In these cases, the forms with the penultimate vowel undergoing centralization do not occur. This provides evidence that in the Eastern dialect, a root-medial homorganic nasal is not in coda position, as I also argue for the case in the Central dialect.

The sets of examples presented here show that the phonological pattern of vowel alternation in Javanese supports the argument for the syllabification of the four word-shapes presented above as follows:

(14) a. $_{\sigma}$CV. $_{\sigma}$CV(C)
b. $_{\sigma}$CV. $_{\sigma}$NTV(C)
c. $_{\sigma}$CV. $_{\sigma}$C$_{stop}$C$_{liquid}$V(C)
d. $_{\sigma}$CVC. $_{\sigma}$CV(C)

where C = any consonant, V = any vowel, N = homorganic nasal, T = clear or breathy stop.

One may argue that words of CVNTVC shape may be syllabified as $_{\sigma}$CV. $_{\sigma}$N. $_{\sigma}$TVC. However, there is no evidence internal to Javanese that suggests that a nasal (homorganic or otherwise) can form a syllable by itself, forming a syllabic nasal. In addition, it would violate the two-syllable template, which is a prevalent feature in PAN language family (e.g. Wolff, 2003). Assuming that all segments are parsed exhaustively into syllables, the post-vocalic homorganic nasal would have to be incorporated to the onset position of the following syllable, sharing the position with the following stop (as suggested in (14b)), given the facts of the vowel alternation.

Earlier in (5), I presented cases where a velar nasal and a fricative are adjacent in root-medial position. With respect to vowel alternation, we see the same pattern for the penultimate vowels in words with the shape of CVNTCV(C). In *maŋsa* 'victim', the vowel /a/ in both the penultimate and the final syllables is realized as [ɔ], giving us [mɔŋsɔ], rather than *[maŋsɔ]. This suggests that the velar nasal following the penultimate vowel is not in coda position. Consequently, the /ŋs/ cluster in root medial position would have to be tautosyllabic as well.

I discuss now the syllabification of NC clusters in word-initial position. We have seen sets of examples, presented earlier in (6-7), which show that NC clusters in word-initial position in Javanese are formed only when a homorganic nasal of a prefix is attached to a root whose initial consonant is a breathy stop. One may provide an argument based on parallel patterning of sounds in the language as a whole. If medial NC clusters are tautosyllabic, a priori it would make more sense for initial NC clusters to be tautosyllabic, too, rather than heterosyllabic. Another view may claim that the word-initial NTs in Javanese are heterosyllabic in that the initial nasal forms its own syllable, e.g. /$_{\sigma}$n$_{\sigma}$t^{ɦ}u$_{\sigma}$laŋ/ 'feed'. In this view, the syllable break would coincide with (or mark) the morphemic break. However, as mentioned earlier, a syllable consisting of only a consonant (nasal or otherwise) is not well-formed in Javanese. Thus, I argue that NC clusters in word-initial position, resulting from morpheme affixation, are tautosyllabic. Note however, that while parallel patterning of the syllable status is maintained between NC clusters in root-medial and word-initial positions, only the breathy NC clusters occur across the prefix + root boundary. This suggests that there is a tension between parallel patterning and a positional restriction. In the case here, parallel patterning is maintained for NC clusters with breathy stops in root-medial and word-initial positions. However, the occurrence of these clusters with clear stops is restricted to the root-medial position; or, the initial position is usually less restrictive and allows for coalescence with the clear stops, thus overcoming parallel patterning.

In the next section, I turn to the pattern of the Indonesian consonants and NC clusters.

5.1.2 Consonants and NC clusters in Indonesian

As is the case with Javanese, the majority of the indigenous roots in Indonesian are bisyllabic. In most cases, they are of the following shape: C(C)V(N)(C)(C)V(C). When there is a sequence of two Cs in root-initial (or root-medial) position, the first C is usually a stop and the second one a liquid. These are less common in Indonesian than in Javanese. Within a root, nasals occurring before other Cs are usually homorganic, and the following C is usually a stop. However, there is a set of words, some of foreign origin, where an alveolar or a velar nasal precedes [s]. Only one consonant may occur in root-final position. With the introduction of borrowed words from other languages, the distribution of consonant clusters in Indonesian has become more complex. In many cases, consonant clusters in borrowed words are simplified either by vowel epenthesis or by consonant deletion (Adisasmito, 1993 and the references therein).

A nasal and a stop may be adjacent in root-medial position. The NC clusters are usually formed by a nasal that takes on the place of articulation of the following voiced or voiceless stop. This is exemplified in (15).

(15) *Root-medial NC clusters in Indonesian*

(a) Voiced stops		(b) Voiceless stops	
timbaŋ	'weigh'	timpaŋ	'limp'
pandaŋ	'look at'	pantaŋ	'be against'
panǰaŋ	'long'	pančaŋ	'stick down'
taŋkap	'catch'	taŋgap	'response'

A nasal could also become adjacent to a stop when a root takes a prefix and/or a suffix. For example, the verbal prefix *meN-* that ends in a placeless nasal may be appended to a root. In (16) are some examples of the NC sequences at the prefix + root boundary.

(16) *NC clusters at prefix + root boundary in Indonesian*

(a) Nasal + voiced stops

/*məN*- + buka/	→ [məmbuka]	'open'
/*məN*- + darat/	→ [məndarat]	'land'
/*məN*- + ǰahit/	→ [məɲǰahit]	'sew'
/*məN*- + ganti/	→ [məŋganti]	'change'

(b) Nasal + voiceless stops/obstruents

/*məN*- + putar/	→ [məmutar]	'turn'
/*məN*- + tuduh/	→ [mənuduh]	'accuse'
/*məN*- + sapa/	→ [məɲapa]	'greet'

/*məN*- + kira/ → [məŋira] 'think'

but:

/*məN*- + /čari/ → [məɲčari] 'look for'

When the root-initial consonant is a voiced stop, the homorganic nasal of the prefix takes on the place of articulation of the stop (16a). When the root-initial consonant is a voiceless stop or the voiceless fricative /s/, the nasal assimilates its place of articulation to the following stop or fricative and coalescence takes place (16b). Note the asymmetry between the voiceless palatal affricate and the voiceless stops. No coalescence takes place when the homorganic nasal of the prefix is adjacent to the voiceless palatal affricate.

Unlike Javanese, there are almost no word-initial NC clusters in Indonesian, except for a small set of words like *mbak* 'title for women (borrowed from Javanese)', *ŋgaʔ* and *ndaʔ* 'no'. This restriction at the root-initial position is in adherence to the sonority hierarchy, whereby nasals are more sonorous than stops (e.g. Clements, 1990). Thus, when a nasal precedes a stop, they would be heterosyllabic so as not to violate the sonority sequencing principle. Assuming parallelism, this leads to the widely held assumption that the root-medial and root-initial NC clusters in Indonesian are heterosyllabic.

A nasal and a stop may also become adjacent at the root and suffix boundaries when a root ends in a nasal and the attached suffix begins with a stop. In the root-final position, nasals maintain a three-way place contrast. When followed by a stop, they do not assimilate in place of articulation to the following stop. This is exemplified in (17a). A nasal may also become adjacent to another nasal in this boundary, as shown in

(17b). Here, too, the place of the coda nasal is maintained. The suffix *-kan* in (17a) indicates that a prepositional phrase follows, implicitly or explicitly. The suffix *-ɲa* in (17b) is a third person possessive clitic.

(17) *Nasal + voiceless stop and nasal + nasal in the root-suffix boundary in Indonesian*

(a) Nasal + voiceless stops

/hantam + kan/	→ [hantamkan]	'smash'
/saran + kan/	→ [sarankan]	'suggest'
/tuaŋ + kan/	→ [tuaŋkan]	'pour'

(b) Nasal + nasal

/ɟ̆arum + ɲa/	→ [ɟ̆arumɲa]	'her needle'
/saran + ɲa/	→ [saranɲa]	'her suggestion'
/tulaŋ + ɲa/	→ [tulaŋɲa]	'her bone'

At the root-prefix boundary, identical consonants may become adjacent, as shown in (18).

(18) *Identical consonants in the root-suffix boundary in Indonesian*

/raŋka-pun/	'frame, emphatic'	/kata-ku/	'my saying'
/raŋkap-pun/	'doubled, emphatic'	/katak-ku/	'my frog'

Lapoliwa (1981) argues that identical consonants in cases like these are phonetically realized as a single consonant, or they undergo degemination. However, acoustically these consonants undergo only partial degemination or shortening (Adisasmito-Smith, 1998). For more discussion in detail of the distribution of consonants in Indonesian, see

MacDonald and Dardjowidjojo (1967), Lapoliwa (1981), Adisasmito-Smith (1998) and the references therein.

5.1.3 Summary

To summarize briefly, vowel alternation in Javanese provides evidence for the argument that medial NC clusters are phonologically tautosyllabic. There is no such evidence in Indonesian. However, the phonological patterning of consonants in the language suggests that medial NC clusters in Indonesian are heterosyllabic.

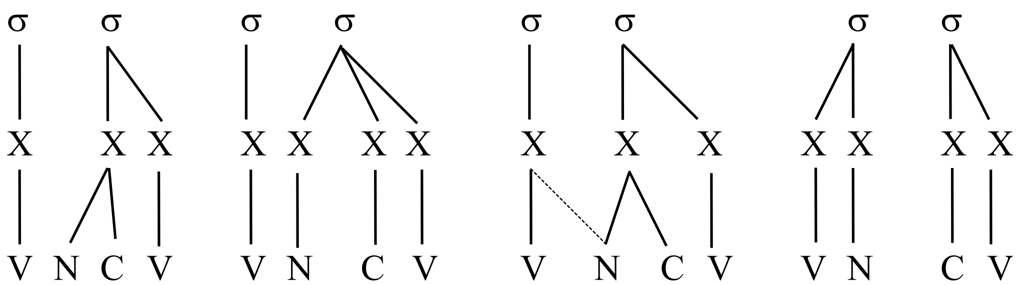
The question that I attempt to address in this chapter is whether the differences in the syllabification of root-medial NC clusters in Javanese and Indonesian are mirrored in the phonetics, and if so, which acoustic pattern is realized for the bilingual speakers of Javanese/Indonesian. If the Indonesian of these bilingual speakers patterns together with that of the monolingual Indonesian speakers, the syllabification of the medial NC clusters would reflect the heterosyllabic pattern. If the Indonesian of these bilingual speakers follows the Javanese pattern, these NC clusters would show the tautosyllabic pattern. First, I turn to studies of NC clusters in other languages and see what predictions can be reached.

5.2 Studies of NC clusters

There have been a number of studies on the phonology and phonetics of NC clusters in various languages. Some of the issues addressed in these studies include, among others, the distribution of NC clusters in a language, their acoustic characteristics, and how they are syllabified based on phonological and/or acoustic examinations. The evidence from previous studies may provide insight as to how NC clusters with different syllable affiliations are acoustically realized in different languages.

The issues most relevant to this chapter are the syllabification of medial NC clusters (tautosyllabic or heterosyllabic) and the segmental status of these clusters (i.e. a complex unit or a sequence of two units). Given their possible syllable affiliation and segmental status, NC clusters in a language may be one of the four logical possibilities presented in (19). An NC cluster may be: (a) a tautosyllabic complex unit, (b) a tautosyllabic cluster of units, (c) a heterosyllabic complex unit, and (d) a heterosyllabic cluster of units. I use "X" to refer to segments without comparing different representations of segmenthood.

(19) (a) (b) (c) (d)



Further restrictions may apply with respect to their position in the syllable (either in onset or in coda position, especially for tautosyllabic NCs) and the voicing of the stop following the homorganic nasal. Here, I discuss the arguments and evidence put forth for the syllable affiliation and segmental status of NC clusters in a range of languages.

In some languages, tautosyllabic NC clusters have been argued to form complex units, namely prenasalized stops. However, the acoustic patterns exhibited by these clusters across languages are by no means uniform. For example, based on their phonotactic constraints, NC clusters in Bantu languages such as LuGanda (e.g. Maddieson and Ladefoged, 1993), Runyambo and KiNdendeule (e.g. Hubbard, 1995) are claimed to be tautosyllabic. The timing pattern of these clusters in Luganda (no duration data for NC clusters in Runyambo and KiNdendeule are available) does not support the claim that they are complex units, in that they are longer than otherwise would be expected. Based on articulatory data, Browman and Goldstein (1986) find that there is no difference in production and timing properties between the heterosyllabic NC clusters in English and the tautosyllabic NC clusters in KiChaka, where the latter are assumed to be complex units. Another case of tautosyllabic NC clusters is found in Fijian (Maddieson, 1989). In this language, the structure of a syllable is strictly CV. The only consonant clusters that occur in word-initial and word-medial positions consist of a homorganic nasal followed by a voiced stop. The consonant distribution -- voiced stops only occur in NC clusters and voiceless stops never follow a nasal -- suggests that nasal + voiced stop sequences are the counterpart of voiceless stops. Acoustic evidence provides further evidence for a NC cluster forming a unit; the durations of these clusters are comparable to those of a single consonant (a stop or a lateral). This suggests that NC clusters in Fijian are treated as a unit, rather than a sequence of units.

The results in these studies indicate that the phonetic duration of tautosyllabic NC clusters, that are claimed to form prenasalized stops may not necessarily reflect their phonological pattern. Maddieson and Ladefoged (1993) suggest that prenasalized stops may exhibit a timing pattern that mirrors their being a unit (i.e. NC $\approx$ C), as is the case with NC clusters in Fijian. On the other hand, they may instead display a timing pattern that reflects their being complex, as opposed to simplex (i.e. NC > C). Luganda would be an example of the second case.

To provide a contrast to tautosyllabic NC clusters, consider the case of the heterosyllabic intervocalic NC clusters in English. The phonotactic constraints of English vowels support the argument for the heterosyllabicity of these clusters. While tense vowels in English can occur in an open or a closed syllable, lax vowels can only occur in a closed syllable; consequently, the homorganic nasal in medial NC clusters following lax vowels in words like [æmbər] and [wɪntər] is in coda position. English also allows NC clusters at the end of a root/word, as in [mɪnt] and [bɛnd]. Consonant clusters, including the NC type, in English have been found to be greater in duration than single consonants (e.g. Umeda, 1977; Vatikiotis-Bateson, 1984).

In addition to the timing organization of the NC clusters, one may also determine the syllable affiliation of intervocalic NC clusters by examining the timing pattern of vowels preceding these clusters. Based on a study of a range of languages, Maddieson (1985) finds that vowels in closed syllables tend to be shorter in duration relative to those in open syllables. Thus, one would expect to see a vowel preceding a heterosyllabic NC cluster, $_{\sigma}$[VN$_{\sigma}$[C, exhibiting shorter duration as compared to a vowel preceding a tautosyllabic NC cluster, $_{\sigma}$[V$_{\sigma}$[NC, since in the former the vowel is in a closed syllable and in the latter it is in an open syllable. Maddieson finds this to be the case in Fijian (Maddieson, 1989), wherein the duration of vowels preceding tautosyllabic NC clusters is comparable to the duration of vowels preceding other intervocalic consonants. Hubbard (1995) also finds this to be the case for vowels preceding tautosyllabic NC clusters vs. intervocalic consonants in KiNdendeule and CiTonga. However, findings in other languages with tautosyllabic NC clusters, such as Luganda (Maddieson and Ladefoged, 1993; Hubbard, 1995), Runyambo (Hubbard, 1995), show that the durations of penultimate vowels in VNCV vs. in VCV cases are not necessarily comparable. In fact, the penultimate vowels in VNCV are longer than in VCV. Based on tone assignment in Luganda and Runyambo, Hubbard (1995) argues that vowels preceding NC clusters are linked to two moras, as compared to vowels preceding intervocalic single consonants that are linked to one mora. In contrast the case of tautosyllabic NC clusters in Fijian, KiNdendeule, CiTonga, Luganda, and Runyambo, intervocalic NC clusters in languages like English and Italian are heterosyllabic. Acoustic findings show that vowels preceding NC clusters in Italian are shorter than vowels preceding intervocalic consonants (Farnetani and Kori, 1986; Smith, 1992). However, this is not always the case, since in English vowels preceding NC clusters are not necessarily shorter than vowels preceding intervocalic consonants (Vatikiotis-Bateson, 1984). Note also, that some acoustic findings contradict Maddieson's claim, in that vowels do not always shorten in closed syllables, e.g. vowels preceding geminate consonants in Sinhala (Letterman, 1994) and in Hungarian (Ham, 1998). These findings suggest that the acoustic properties of a sequence of segments are not the only factor affecting the acoustic outcome of the segment timing organization. Language-specific constraints seem to contribute also to the equation.

With respect to the duration of Indonesian and Javanese vowels, we may find that vowels preceding a tautosyllabic NC cluster in Javanese and those preceding an intervocalic consonant are of comparable duration, similar to the case in Fijian, and vowels preceding a heterosyllabic NC cluster in Indonesian are shorter than those preceding an intervocalic consonant, similar to the case in Italian. However, it is also possible for vowels in Javanese to be longer preceding a NC cluster vs. an intervocalic consonant, similar to the case in Luganda, and for vowels in Indonesian to be of comparable duration preceding a NC cluster vs. an intervocalic consonant, similar to the case in English.

Another compelling piece of evidence for differences in the syllabification of NC clusters is based on the degree of nasalization that the nasal portion of NC clusters has on the preceding vowel. Comparing two Bantu languages, LuGanda and Sukuma, Maddieson and Ladefoged (1993) find that a vowel preceding a prenasalized stop in LuGanda shows little or no anticipatory nasalization, while a vowel preceding a heterosyllabic NC cluster in Sukuma shows more marked nasalization effect from the nasal. The spectrograms in Figure 5.1 show the examples from LuGanda and Sukuma.

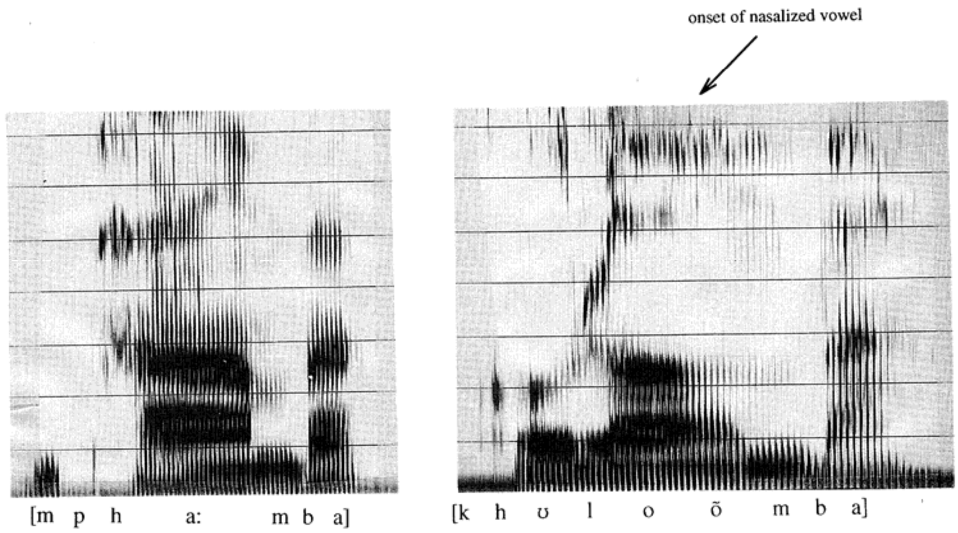


Figure 5.1: Spectrograms of LuGanda /mpamba/ and Sukuma /kʊlomba/ (from Maddieson and Ladefoged (1993), reproduced with permission)

As shown here, the vowel in Sukuma shows a greater effect of nasalization as can be seen in the change in the formants' intensity midway through the vowel. While no quantitative data were available for these forms, the difference shown here is at least visually quite evident.

To summarize, the results in the acoustic studies discussed in this section suggest that the phonetic pattern of NC clusters may not be indicative of the phonological pattern of these clusters, such as their syllable affiliation. This further suggests that, even though many phonological features have been shown to have a phonetic correlate, it is possible for certain phonological structures to not be reflected in the phonetics. With respect to NC clusters, Ladefoged and Maddieson (1986) propose that "… the motivation for talking of prenasalized stops, rather than of a nasal + stop sequence, is often phonological rather than phonetic

…" (50). If this is the case, the acoustic measurements may not (always) reflect the phonological observations.

However, it is still worth pursuing this question, by looking at additional cases. Based on previous acoustic studies on NC clusters and the phonotactic constraints in Indonesian and Javanese, there are three predictions that can be made about the possible findings for these two languages.

Prediction 1: we would find that in Javanese, vowels preceding medial consonants and those preceding medial NC clusters are comparable in duration reflecting the status as being wholly in the onset, while in Indonesian, the penultimate vowels are shorter preceding NC clusters than preceding single consonants. In addition, the bandwidth of the penultimate vowels in these two languages may reflect the different syllable affiliation of the NC clusters in the respective language; in Indonesian the homorganic nasal in coda position may exhibit greater nasalization on the preceding vowel resulting in wider bandwidth toward the end of the vowel, while in Javanese the formant bandwidth may be similar throughout the duration of the vowel preceding the homorganic nasal in onset position.

Prediction 2: we may find that for Javanese, the duration of the tautosyllabic NC clusters is comparable to the duration of single segments, which would indicate that these clusters behave as a complex unit, rather than a sequence of segments; or, we may find that the duration of the Javanese NC clusters is greater than the duration of single consonants, which would reflect the two-segment composition of the cluster. If the Indonesian NC clusters are indeed heterosyllabic, we would predict to see their duration to be greater than the duration of single consonants.

Prediction 3: we may see that despite the different phonological patterns and phonotactic constraints in Indonesian and Javanese, the duration facts of the vowels and the bandwidth of vowels do not reflect these differences. In this case, then, the phonological phenomenon is not mirrored in the phonetics.

In the following section, I present the methods for obtaining the acoustic measurements, which are discussed in § 5.4.

5.3 Methodology

The acoustic study carried out in this chapter includes the analysis of segment durations in bisyllabic words, particularly the durations of penultimate vowels and medial consonants (stops, nasals, and NC clusters), and the measurements of H1-A1 values (as the acoustic correlate of F1 bandwidth) at the 50% and 75% points of the penultimate vowels. The word shapes are CVCVC vs. CVNCVC for Indonesian, and CVCV vs. CVNCV for Javanese.

Segment durations are obtained by measuring the distance between the beginning and the end of a segment, marked by specified labels, as outlined in Chapter 2. While the bandwidth of all formants of a vowel would be affected when nasal quality is present, the bandwidth of the first formant is seen to bear the highest degree of effect (e.g. House and Stevens, 1956). In the investigation here, the nasalization effect realized on the F1 bandwidth of penultimate vowels is quantified using the method to measure the F1 bandwidth of vowels following breathy stops. In this technique, F1 bandwidth is assessed by way of an acoustic measure, whereby the differences of the amplitude values of the first harmonic (H1) and of the first formant (A1) are compared (H1-A1) (e.g. Hanson, 1997). The correlation between H1-A1 measurement and F1 bandwidth is that if the difference of amplitude values of the first harmonic and first formant of a vowel is greater in environment A than in environment B, then the F1 bandwidth of that vowel is greater in environment A than when in environment B. A pattern that we would expect to see is that if a vowel is nasalized, it would have greater H1-A1 value, and thus broader F1 bandwidth, as compared to a non-nasalized (or oral) vowel.

The amplitude values of the first harmonic and the first formant of the target vowels are adjusted to neutralize the effect of the different ranges of fundamental frequency between male and female speakers. The adjustment is computed using the formula proposed by Hanson (1997). The results of the measurements in this chapter are pooled across the speakers (one female and two male Javanese speakers, and two female and one male monolingual Indonesian speakers).

The target vowel is /a/ in both Indonesian and Javanese. The realization of this vowel is [a] in Indonesian and [ɔ] in Javanese. The words analyzed here are shown in (20).

(20)	*Indonesian*		*Javanese*	
	padas	‘rock’	rɔkʱɔ	‘body’
	sadar	‘conscious’	sɔkʱɔ	‘k.o. tree’
	patah	‘break’	rɔkɔ	‘brother’
	satar	‘nonsense word’	sɔkɔ	‘pillar’

panas	‘hot’	rɔŋɔ	‘nonsense word’
sanar	‘nonsense word’	sɔŋɔ	‘nine’
pandas	‘nonsense word’	rɔŋgʱɔ	‘noble title’’
sandar	‘lean on’	sɔŋgʱɔ	‘support’
pantas	‘fit’	rɔŋkɔ	‘skeleton’
santap	‘eat’	sɔŋkɔ	‘suspect’

The speech of six speakers, including three monolingual Indonesian speakers (two female and one male speakers) and three bilingual Central Javanese/Indonesian ones (one female and two male speakers) is examined. The total number of the Indonesian tokens analyzed is 120 (3 speakers x 10 words x 4 repetitions) for each speaker group. The number of the Javanese tokens is 120 (3 speakers x 10 words x 4 repetitions).

The measurement results are statistically analyzed using One-Way ANOVA’s. A difference with a p-value smaller than .05 is taken to be statistically significant. The duration measurements for the individual speaker are presented in Appendix E.

Given the differences of Indonesian and Javanese in the syllabification of NC clusters, we would expect to find acoustic differences as shown in the following Table 5.1.

Table 5.1: Expected acoustic results in Javanese and Indonesian

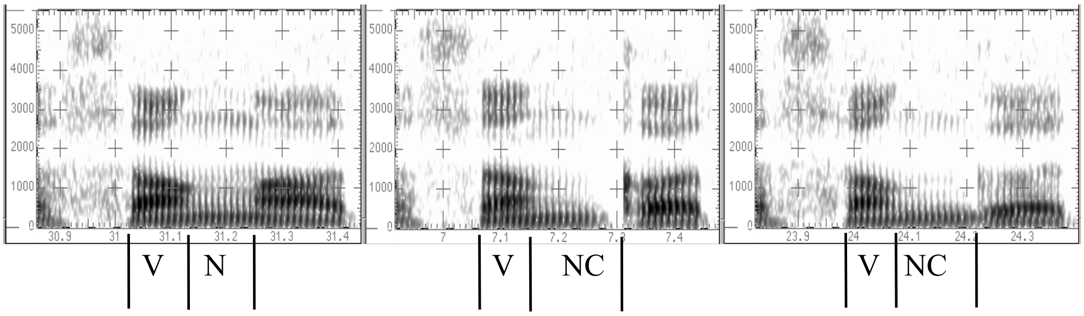
Syllabification of NC	tautosyllabic in Javanese	heterosyllabic in Indonesian
Duration of penultimate vowels	V-preNC ≈ V-preC or V-preNC ≈ V-preN	V-preNC < V-preC or V-preNC V-preN
F1 bandwidth of penultimate vowels	V-preNC ≈ V-preN	V-preNC > V-preN
Duration of NC	NC >/≈ N or NC >/≈ C	NC > N or NC > C

In the next section, I present the acoustic results of the durations of penultimate vowels and root-medial consonants, and of F1 bandwidth of penultimate vowels.

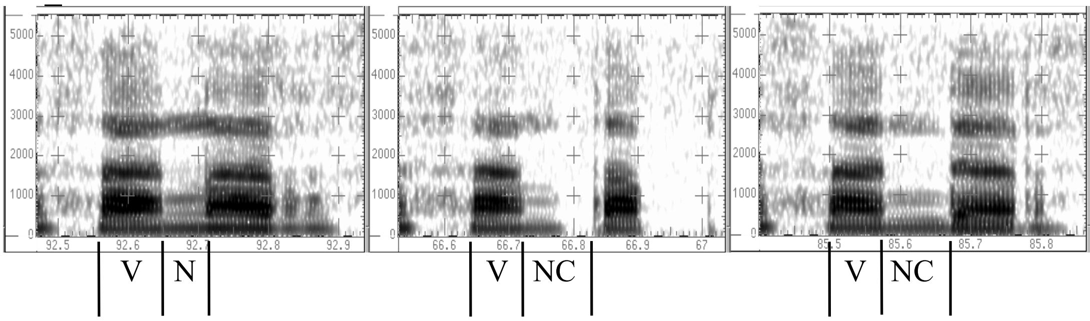
5.4 Acoustic measurements and analyses of Javanese and Indonesian NC clusters and pre-NC vowels

First, we start with an impressionistic observation of duration and degree of nasalization from the set of sample spectrograms presented in Figure 5.2. The penultimate vowels and the root-medial consonants in question are delimited by two vertical lines

(a) Javanese [sɔŋɔ], [sɔŋkɔ] and [sɔŋgɔ] by the Javanese Speaker CJ_m6



(b) Indonesian [sanar], [santap] and [sandar] by the monolingual Speaker IM_m7



(c) Indonesian [sanar], [santap] and [sandar] by the bilingual Speaker CJ_m6

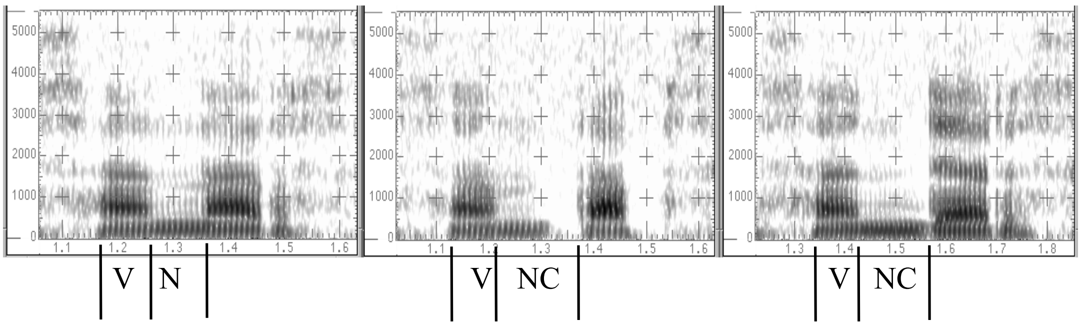


Figure 5.2: Sample spectrograms of penultimate vowels preceding an intervocalic nasal and a NC cluster in Indonesian and Javanese

Each language is illustrated with a set of three spectrograms, where the spectrograms show a case of a penultimate vowel preceding an intervocalic nasal (the left most spectrograms), a NC cluster with a voiceless stop (the middle spectrograms), and a NC cluster with either a voiced stop (for Indonesian) or a voiced breathy stop (for Javanese) (the right most spectrograms). In (a) are the spectrograms of the Javanese words [sɔŋɔ], [sɔŋkɔ], and [sɔŋgɔ], as produced by a Central Javanese speaker. In (b) are the spectrograms for the Indonesian words [sanar], [santap], and [sandar], as produced by a monolingual speaker. In (c) are the spectrograms of these Indonesian words, as produced by a bilingual speaker from Central Java.

Looking at the set of spectrograms in (a), the Javanese penultimate vowels seem to be of similar duration in the words [sɔŋɔ], [sɔŋkɔ], and [sɔŋgɔ]; if the Javanese penultimate vowels in these words are in an open syllable, this similarity is consistent with what we would expect. The duration of the intervocalic nasal seems to be slightly shorter than the durations of the NC clusters, which would indicate the difference of the duration of one unit vs. that of two units (or a complex unit). In these spectrograms, the formants of the penultimate vowel seem to broaden towards the end of the vowel that may indicate the nasalization effect of the velar nasal; velar nasal has been found to result in greater nasalization on vowels in Chinese (Chen, 2000). Lacking recorded tokens with the intervocalic alveolar nasal and NC clusters for Javanese to contrast with the alveolar case for Indonesian in (b) and (c), we need to be careful in drawing conclusions of the comparisons between the Javanese vs. Indonesian cases.

In the set of spectrograms in (b) of the Indonesian words [sanar], [santap], and [sandar] for a monolingual speaker, we could see that the penultimate vowels preceding the NC clusters are slightly shorter than the vowel preceding the intervocalic nasal. This would be what we expect if the NC clusters are heterosyllabic, and consequently, the preceding vowels are in a closed syllable. Comparing the root-medial consonants, the intervocalic nasal seems to be slightly shorter in duration than the NC clusters, as would be expected for the duration of a segment vs. two segments. With respect to the formants of the penultimate vowel, they seem to be narrow throughout the duration of the vowel for all three words, which may indicate little, if at all, nasalization effect. The vowel formants in the set of spectrograms in (b) are similar to the one for LuGanda (shown in Figure 5.1), where NC clusters are claimed to be tautosyllabic (Maddieson and Ladefoged, 1993). This similarity is interesting, since NC clusters in Indonesian are assumed to be heterosyllabic, while in LuGanda they are tautosyllabic. This may suggest that the relationship between nasalization effect on vowel and nasal syllable affiliation is not straightforward.

The spectrograms in (c) show the production of the Indonesian [sanar], [santap], and [sandar] by a bilingual Central Javanese speaker. The penultimate vowels preceding the intervocalic nasal and the NC clusters seem to be of similar duration. The NC clusters seem to be greater in duration as compared to the intervocalic nasal, as would be expected for the duration of a unit vs. two units. The formants of the penultimate vowels seem to be as narrow throughout the whole vowel for all three words. As mentioned earlier, the sets of spectrogram samples presented here are not unique to these speakers for these particular tokens, but rather they seem to be common for all monolingual Indonesian and the bilingual speakers, whose speech is analyzed here, and for the other repetitions of these Indonesian words. The spectrograms of the Indonesian words for the bilingual Javanese speaker in (c) may reflect a pattern of the monolingual Indonesian speakers, or they may reflect the Javanese influence on their Indonesian.

What we would expect to see in the acoustic results is that they would reflect the different syllable affiliation of the nasals in the intervocalic and in the NC cluster cases in Javanese vs. Indonesian. The results presented here are organized as follows. In § 5.4.1, I present the durations of Javanese penultimate vowels preceding NC clusters vs. intervocalic consonants, the durations of these consonants, and the H1-A1 values of the penultimate vowels, as produced by the Central Javanese speakers. In § 5.4.2, I present the acoustic measurements of Indonesian penultimate vowels and medial consonants, as produced by the monolingual speakers of Indonesian, and in § 5.4.3, the production of the Indonesian tokens by the bilingual Central Javanese/Indonesian speakers.

5.4.1 Javanese penultimate vowels and medial consonants

In Chapter 3, I show that vowel alternation in Javanese provides evidence for the syllable affiliation of root-medial NC clusters, in that the homorganic nasal is not in coda position. If this phonological characteristic of Javanese medial NC clusters is mirrored in the phonetics, we would expect to see the following acoustic results. The durations of a penultimate vowel preceding single consonants and those preceding NC clusters are comparable; the H1-A1 values of the vowels preceding an intervocalic nasal and preceding a homorganic nasal are similar; and the durations of single consonants and NC clusters may be equivalent, that is, if the NC clusters function as a single unit.

I first present the mean durations of vowels preceding intervocalic stops and nasals, and preceding NC clusters, in Figure 5.3. Then I present the measurement results of H1-A1 values of these vowels, followed by the average durations of the intervocalic consonants.

In Figure 5.3, the bars represent the mean durations pooled across three speakers. Under each bar, a caption indicates the penultimate vowels and the following consonant(s). **V-preT** refers to penultimate vowel preceding a clear voiceless stop, **V-preT^{ɦ}** preceding a voiceless breathy stop, **V-preN** preceding a nasal, **V-preNT** preceding a homorganic nasal + a voiceless clear stop, and **V-preND^{ɦ}** preceding a homorganic nasal + a voiceless breathy stop.

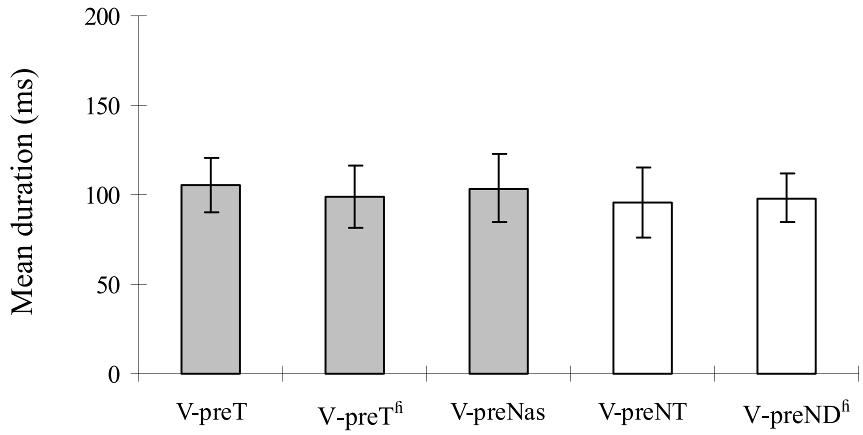


Figure 5.3: Mean durations (ms) of Javanese vowels preceding intervocalic stops and nasals vs. NC clusters, as produced by the Central Javanese speakers

The durations of the penultimate vowels are comparable across the board, with the difference of 10 ms between the greatest (V-preT) and the smallest (V-preNT). Recall that Javanese clear and breathy stops are voiceless, as discussed in Chapter 4; thus, the comparable durations of vowels preceding the two contrastive stops are as expected. The durations of V-preT^{ɦ} and those of V-preND^{ɦ} are practically identical. Statistically, the differences among these vowels are not significant. These results indicate that in Javanese, vowels have similar durations when preceding intervocalic consonants or NC clusters. This suggests that there is no vowel shortening preceding a NC cluster. Given the vowel alternation in Javanese which provides support for the argument that the nasal portion of NC clusters is in onset position, these results are as expected.

Note, however, that it is possible for penultimate vowels in Javanese to have the same duration whether or not the following consonant cluster is NC. In order to consider this possibility, a preliminary acoustic investigation of the durations of Javanese penultimate vowel in CVCVC vs. CVCCVC words was undertaken. This included measurements for penultimate vowels preceding root-medial consonants like the following: /rs/ vs. /r/, /rn/ vs. /r/, and /rm/ vs. /m/ (see data in (11) in § 5.1.1 for examples). The results show that penultimate vowels preceding consonant clusters are shorter than those preceding single consonant, even though the differences are relatively small: overall 14 ms. The ratio of V-preC vs. V-preCC is 1.2:1, and thus vowels do shorten (slightly) in closed syllables. Future study on the timing pattern of penultimate vowel in Javanese preceding a single consonant vs. a sequence of consonants in medial position would need to include other possible combinations of consonants in this position (beyond those presented in (11), though there are few such clusters and many are only in borrowing). However, these preliminary results do support the conclusion that penultimate vowels in Javanese undergo at least modest shortening preceding a sequence of consonants other than a sequence of nasal + stop.

I turn now to the measurement results of the H1-A1 values. If the nasal portion of NC clusters is in onset position, we would expect to see the H1-A1 values, and thus the F1 bandwidth, to be comparable for vowels preceding an intervocalic nasal and preceding a NC cluster. If a vowel is nasalized, its H1-A1 values would be greater as compared to the values for a non-nasalized vowel. The results are presented in Figure 5.4.

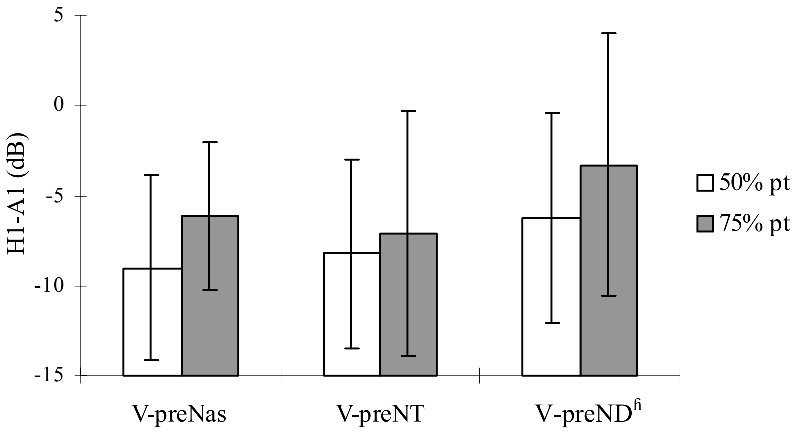


Figure 5.4: Mean H1-A1 values (in dB) of Javanese vowels preceding intervocalic nasals vs. homorganic nasals in NC clusters, as produced by the Central Javanese speakers

For vowels preceding intervocalic nasals, the H1-A1 values are almost 1 dB lower than for those preceding NT, and 3 dB lower than for those preceding NDɦ, at the 50% point. At the 75% point, the H1-A1 values for vowels preceding nasals are greater by 1 dB as compared to the values for those preceding NT, and lower by 3 dB as compared to the values for those preceding ND^{ɦ}. Statistically, these differences are not significant.

Isolating the results at the 50% point in the vowel, one may suggest that the small increase of the H1-A1 values when comparing the N cases vs. the NT/ND^{ɦ} cases, indicates a slight broadening of F1 bandwidth. However, the results at the 75% point in the vowel do not support this.

The difference of 2-4 dB of the H1-A1 values for vowels preceding ND^{ɦ} vs. NT/N at both the 50% and 75% points may be small; however, it may suggest that there is a low level anticipatory effect on the preceding vowel, due to the breathy quality of the stop. These results may also indicate that the determining factor for the nasal effect to take place is not the syllable affiliation but rather the manner of articulation of the following segment. This is to say that since Javanese NC clusters are phonologically in onset position, and if the difference in F1 bandwidth between V-preND^{ɦ} vs. V-preNT/V-preN makes some difference, these may suggest that the F1 bandwidth broadening results from the fact that the following consonants are nasal and breathy stop, rather than from the fact that these consonants are in onset position. Both nasals and breathy (voiced) stops have the effect of broadening F1 bandwidth. In anticipation of both these adjacent segments, the F1 bandwidth of the preceding vowels may be maximally broadened.

We also see in Figure 5.4 that when the H1-A1 values at the 50% and 75% points are compared, those at the 75% point are greater. Even though statistic analysis shows that the H1-A1 value differences at the two different points are significant only for V-preN cases, this tendency suggests that the F1 bandwidth of vowels becomes broader at the point closer to the following nasal, exactly what we would expect to see from coarticulation.

I turn now to the measurement of the durations of medial consonants. We would expect the durations of stops and nasals to be comparable, but the durations of the NC clusters may or may not be comparable to the single intervocalic consonants. The results are presented in Figure 5.5.

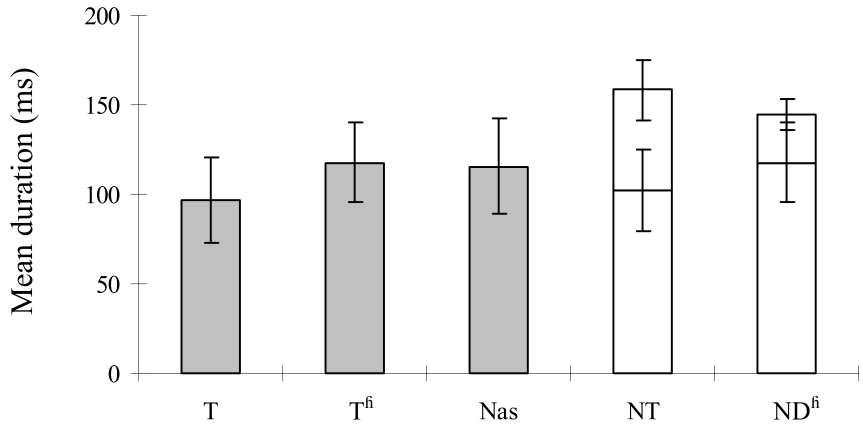


Figure 5.5: Mean durations (ms) of Javanese intervocalic stops and nasals vs. NC clusters, as produced by the Central Javanese speakers

The durations of voiceless clear stops are relatively shorter than those of voiceless breathy ones, by 18%. We have seen earlier in Chapter 5 that, for the bilingual Javanese/Indonesian speakers, Indonesian voiceless stops are shorter than the voiced ones, and the latter are acoustically realized as voiceless. The durations of single stops are shorter than those of NC clusters; the duration ratio for T:NT is 1:1.6 and for T^{fi}:ND^{fi} is 1:1.2. Intervocalic nasals have similar durations as compared to the breathy stops. The durations of these nasals and the nasal portion of $ND^{ɦ}$ are also similar, while the homorganic nasal in NT is slightly shorter by 14% as compared to the homorganic one in $ND^{ɦ}$.

The durations of the clear stop in NC clusters are twice as long as those of the breathy stop. Recall that Javanese breathy stops in NC clusters are acoustically realized with a voice bar during the stop closure, indicating their voiced status.

The duration differences in Figure 5.5 are statistically significant ($p < .05$) for T vs. NT, $T^{ɦ}$ vs. $ND^{ɦ}$, N vs. NT, N vs. $ND^{ɦ}$, for the nasal portion in NT vs. $ND^{ɦ}$, and for T vs. $T^{ɦ}$ in NC clusters. These differences are not significant for T vs. $T^{ɦ}$, T vs. N, $T^{ɦ}$ vs. N, NT vs. $ND^{ɦ}$, and N vs. the nasal portion in NT. These results suggest that in Javanese, (1) a stop or a nasal is shorter in duration as compared to a NC cluster, and (2) the duration of the nasal and stop in a NC cluster are complementary and are determined by the voice quality (or voicing) of the stop in that the breathy stop realized as voiced tends to be quite short compared to the modal stop realized as voiceless, and the following nasal tends to be longer preceding a voiced breathy stop and shorter preceding a voiceless (modal) stop.

To summarize, the acoustic measurements in this section indicate that Javanese penultimate vowels in words of the shape CVNCV do not undergo shortening, relative to the penultimate vowels in CVCV and CVNV words. F1 bandwidth, predicted to be similar for vowels preceding the intervocalic nasal and NC clusters, does not exhibit a systematic pattern of the anticipated result. The durations of the medial NC clusters share the timing pattern of a cluster of segments, rather than that of a single segment (cf. Fijian case (Maddieson, 1989)). Thus far, of the three acoustic measurements carried out in this chapter, the duration of penultimate vowels is the only acoustic evidence that provide clear support for the tautosyllabic status of the Javanese root-medial NC clusters.

In the next section, I turn to the acoustic measurements of the Indonesian vowels, stops, and nasals as produced by the monolingual speakers. If the Indonesian NC clusters are heterosyllabic and their phonological pattern is reflected in the phonetics, we would expect to see the penultimate vowels to be longer preceding an intervocalic nasal than preceding a NC cluster. We may also see the F1 bandwidth of the penultimate vowels to be greater preceding a NC cluster than preceding an intervocalic nasal.

5.4.2 Indonesian penultimate vowels and medial consonants by the monolingual Indonesian speakers

I first present the average durations of vowels preceding intervocalic stops, nasals, and NC clusters. Then I present the acoustic correlate of F1 bandwidth of these vowels, followed by the average durations of the intervocalic consonants. The results are consistent across the three speakers, and therefore they are being pooled here.

The chart in Figure 5.6 shows the average durations of Indonesian penultimate vowels for the monolingual Indonesian speakers. Under each bar in the chart, a caption indicates the penultimate vowels and the following consonant(s). **V-preT** refers to the penultimate vowel preceding a voiceless stop, **V-preD** preceding a voiced stop, **V-preN** preceding a nasal, **V-preNT** preceding a homorganic nasal + a voiceless stop, and **V-preND** preceding a homorganic nasal + a voiced stop. Gray bars refer to vowels preceding an intervocalic consonant (stop or nasal), and white bars refer to vowels preceding a NC cluster. Each bar has a vertical bar representing two standard deviations.

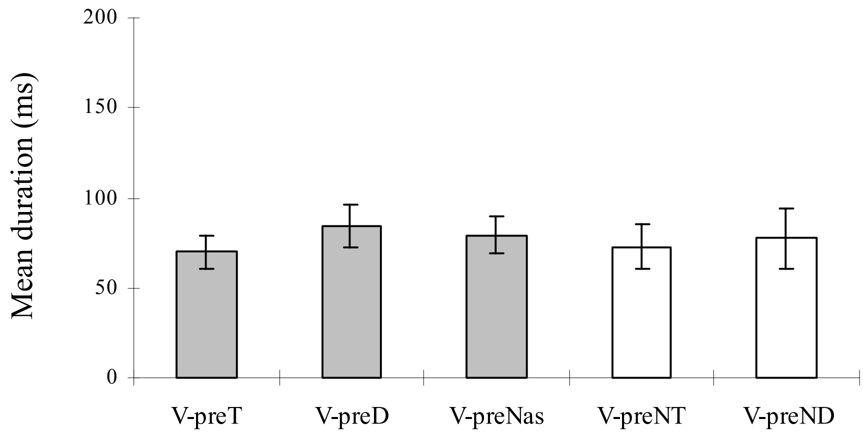


Figure 5.6: Mean durations (ms) of Indonesian vowels preceding intervocalic stops and nasals vs. NC clusters, as produced by the monolingual Indonesian speakers

The durations of penultimate vowels preceding voiceless stops are shorter than those preceding voiced stops and nasal, as expected (e.g. House and Fairbanks, 1953; Peterson and Lehiste, 1960; Chen, 1970; Port, 1981, among others). Preceding voiceless stops, vowels are 17% shorter as compared to those preceding voiced stops and 11% shorter as compared to those preceding nasal. Vowels are also slightly shorter preceding voiceless NC clusters than preceding the voiced ones. The durations of vowels preceding voiceless stops and preceding voiceless NC clusters (V-preT vs. V-preNT) are comparable. The durations of vowels preceding voiced stops (V-preD) are slightly greater than those preceding voiced NC clusters (V-preND). The durations of vowels preceding an intervocalic nasal are slightly greater than those preceding either voiceless or voiced NC clusters. Statistical analyses indicate that the differences in duration of the penultimate vowels are significant ($p < .05$), for V-preT vs. V-preD and for V-preD vs. V-preNT. These results also show that there is a bit of a confound with vowel lengthening before voiced consonants, irrespective of syllabification, even though the differences are not the magnitude that we would expect.

I turn now to the measurements of the H1-A1 values of vowels preceding an intervocalic nasal vs. voiced and voiceless NC clusters understood to be heterosyllabic, in bisyllabic Indonesian words. If degree of syllabification is affected by syllable affiliation (measured here as vowel F1 bandwidth, associated to H1-A1 value), what we would expect to see here is that the H1-A1 value for vowels preceding an intervocalic nasal in onset position is lower than for vowels preceding a nasal portion of a NC cluster, assumed to be in coda position in Indonesian. In Figure 5.7, I show the results of the differences between the amplitude values of the first harmonic and those of the first formant (H1-A1) for Indonesian vowels in penultimate syllables. Recall that there is practically no visible nasalization effect on the penultimate vowel preceding the two different types of nasal, for the monolingual speakers, as shown earlier in the spectrographic illustration in Figure 5.2. This is consistent with our impressionistic observations.

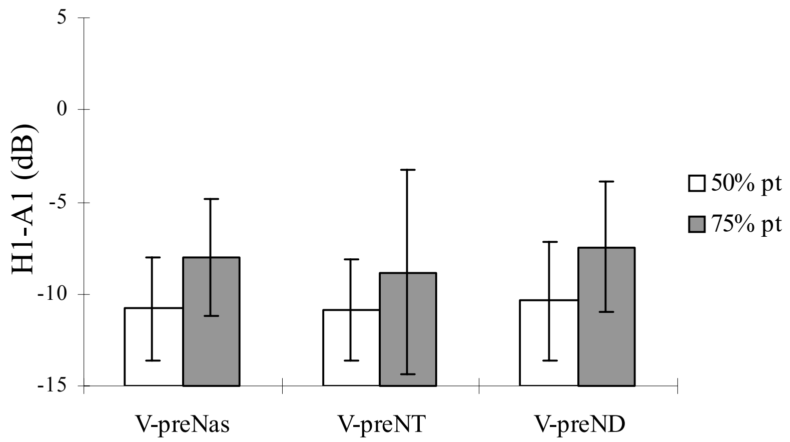


Figure 5.7: Mean H1-A1 values (in dB) of Indonesian vowels preceding intervocalic nasals vs. homorganic nasals in NC clusters, as produced by the monolingual Indonesian speakers

These results show that at the 50% point, the mean H1-A1 values are no different for vowels preceding an intervocalic nasal and for vowels preceding a homorganic nasal in the NT and ND clusters. At the 75% point, the mean H1-A1 value for vowels preceding NT clusters is the lowest and that for vowels preceding ND clusters is the highest, with only 2 dB difference. These differences are not statistically significant. It is interesting to note that the H1-A1 values of vowels at the 75% point are greater than at the 50% point, suggesting that vowels have wider F1 bandwidth at the point nearer to the following nasal.

The results here suggest that the F1 bandwidths of these vowels are similar; this, in turn, indicates that vowels are no more nasalized preceding an intervocalic nasal (in onset position) than preceding a nasal portion of a NC cluster (hypothesized to be in coda position). Considering the phonotactic constraints in Indonesian, whereby the two types of nasal have different syllable affiliation, these results are striking.

This might suggest the need to readdress the issue of the syllable affiliation for these Indonesian nasals. Or it may suggest that the different syllable affiliation of these nasals is simply not expressed in the degree of nasalization. Syllable affiliation does not seem to have much effect on degree of nasalization in either Sundanese, French, or English (Cohn, 1990). The issue of NC syllabification in Indonesian is discussed in further depth in § 5.5.

Further comparisons between the H1-A1 values for Javanese (shown in Figure 5.4) and for the Indonesian of the monolinguals indicate that the range of values for Javanese penultimate vowels is greater than for Indonesian. This suggests that F1 bandwidth for Javanese penultimate vowels (preceding an intervocalic nasal and NC clusters) tends to be greater than for Indonesian.

I turn now to the acoustic durations of the root-medial stops, nasals, and NC clusters. What we would expect to see here is that the durations of a sequence of two segments like NC clusters are greater than the duration of any single segments. This is indeed the case, as shown in Figure 5.8. In this chart, gray bars refer to single consonants and white bars to NC clusters.

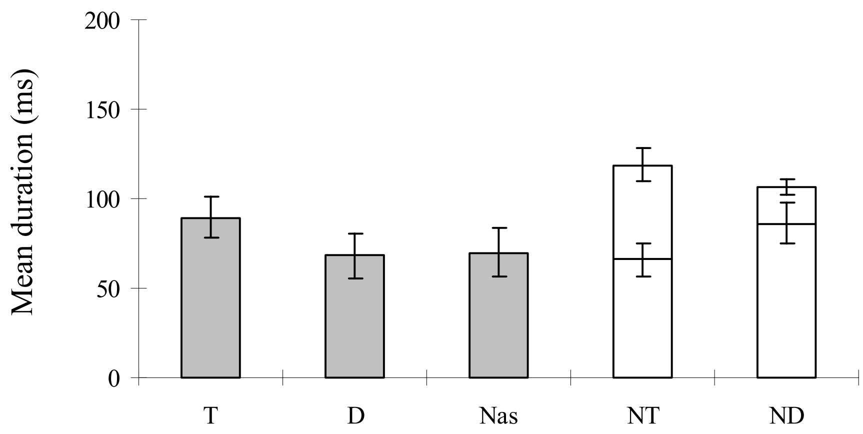


Figure 5.8: Mean durations (ms) of Indonesian intervocalic stops and nasals vs. NC clusters, as produced by the monolingual Indonesian speakers

The results show that the mean durations of the medial single consonants tend to be smaller than those of the NC clusters. The ratios of the differences are 1:1.3 for T:NT and 1:1.6 for D:ND. The voiced stops are shorter in duration than the voiceless ones with the ratio of 1:1.3. The tendency of duration difference between stops with different voicing is commonly observed in different languages (e.g. Chen, 1970). The duration differences due to stop voicing are also reflected in the NC clusters, with the ratio of 1:2.5 for D in ND vs. T in NT. This ratio is much bigger than the ratio for the intervocalic stop cases, consistent with the NT vs. ND pattern seen in English, French, and Sundanese (Cohn, 1990).

The durations of the intervocalic nasals and the voiced stops are comparable. The durations of an intervocalic nasal are shorter than those of the homorganic nasal followed by a voiced stop, but comparable to those of the nasal followed by a voiceless stop. The ratio differences between the homorganic nasal in NT and that in ND are 1:1.2.

The duration differences are statistically significant ($p < .05$) for T vs. D, T vs. N, T vs. NT, D vs. ND, N vs. NT, N vs. ND, and N vs. the nasal portion of ND. The differences are not significant for D vs. N, and N vs. the nasal portion of NT.

These results suggest that the timing patterns of NC clusters in Indonesian reflect the characteristics of a sequence of two segments, in that their durations are greater than the durations of single segments (a stop or a nasal). Comparing the durations of the segments that make up the NC clusters, we can see the effect of duration trade-off; the shorter nasal portion is followed by the longer voiceless stop, while the longer nasal portion is followed by the shorter voiced stop. This may suggest a durational 'target' for these NC clusters. Comparisons of durations of the intervocalic consonants (a stop or a nasal) and the nasal + stop sequences at the root-initial and -final positions with those cases at the root-medial position may provide further insight to the timing pattern of intervocalic consonants and consonant clusters.

The overall acoustic measurements for the Indonesian of the monolingual speakers in this study indicate that penultimate vowels are acoustically similar in terms of duration and F1 bandwidth whether they precede an intervocalic nasal or a medial NC cluster. Consequently, the acoustic results for these vowels do not support the theoretical argument that an intervocalic nasal is in onset position and that the nasal portion of a medial NC cluster is in coda position.

It is interesting to note that the duration values for the intervocalic consonants and NC clusters are shorter for Indonesian than they are for Javanese (shown in Figure 5.5). This is also the case with the duration of the penultimate vowels: it is shorter in Indonesian (for the monolinguals) than it is in Javanese. The duration results of Indonesian and Javanese that we have seen so far may indicate different rates of speech, whereby the monolingual Indonesian speakers employed faster speech than the bilingual speakers. Studies on speech rate have shown that segments tend to be shorter in fast speech than in slower speech (e.g. Gay, 1978; Port, 1981; Crystal and House, 1988, and others). If this is the case with the Indonesian of the monolinguals vs. Javanese, we might expect greater nasalization effect in the Indonesian of the monolinguals, e.g. greater F1 bandwidth, and thus H1-A1, for the pre-nasal penultimate vowels. However, the results suggest the opposite. The H1-A1 values for the penultimate vowels for Javanese are greater than for Indonesian, suggesting that the F1 bandwidth of the pre-nasal penultimate vowels in Javanese is greater than the F1 bandwidth of these vowels in Indonesian.

To my knowledge, no study has been carried out yet on the influence of speech rate on vowel F1 bandwidth or on the degree of nasalization. However, speech rate has been found to affect the timing of velum lowering for pre-nasal vowels, such as in Spanish (Solé, 1992), whereby the portion of pre-nasal vowels that is nasalized is longer in fast speech rate than in slower speech rate. The paradoxical facts about duration and F1 bandwidth for Indonesian vs. Javanese suggest that the differences found in vowel and consonant durations may not be due to the difference in speech rate of the monolingual Indonesian speakers vs. the

Javanese speakers. It is also possible that these two speaker groups employ different speech rates, thus the differences in segment durations. However, there may be some other factor operating that has greater effect on F1 bandwidth, such as place of articulation. Recall that the place of articulation of the target consonants (root-medial stops, nasals, and NC clusters) is alveolar for the Indonesian cases and velar for Javanese. Velar nasal, having the oral constriction farther back as compared to alveolar nasal, is argued to be less consonantal and '… therefore not be too dissimilar from a flanking nasalized vowel' (Ohala and Ohala, 1993). In addition, Chen (2000) finds that velar nasal in Chinese results in greater nasalization on vowels as compared to alveolar nasal. The case with the Javanese vowel exhibiting greater F1 bandwidth (and thus greater nasalization) preceding a velar nasal than the Indonesian vowel preceding an alveolar nasal seems to be parallel to the case in Chinese.

So far, we have seen that the results for Javanese are as expected, but that the results for the Indonesian for the monolinguals are not really as expected. Consequently, we will not be able to diagnose the influence of Javanese on the Indonesian of the bilinguals as clearly as hoped.

In the following section, I present the acoustic measurements of the Indonesian penultimate vowels and medial consonants, as produced by the bilingual speakers. What we would expect to see in the Indonesian of the bilinguals is the tendency for segment duration and vowel F1 bandwidth to be greater than in the Indonesian of the monolinguals.

5.4.3 Indonesian penultimate vowels and medial consonants by the bilingual Central Javanese/Indonesian speakers

In the charts in this section, the Indonesian voiced stops in the intervocalic position are represented as “D”, and as N“D” in the NC clusters. As discussed in Chapter 4, Indonesian voiced stops in the intervocalic position are acoustically realized as voiceless by these bilingual speakers, i.e. there is no voice bar during the stop closure. In addition, acoustic measurements indicate that these stops are breathy. In the NC cluster cases, while it is realized as voiced, it is also breathy. The durations of the Indonesian penultimate vowels are presented in Figure 5.9.

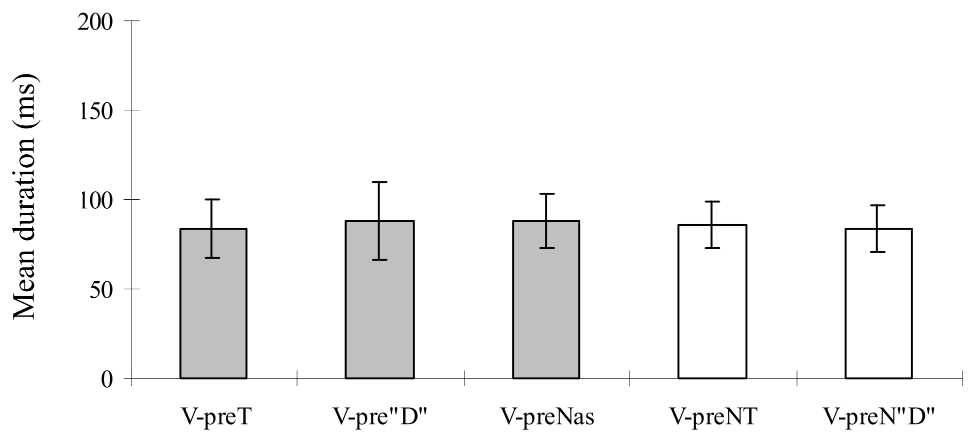


Figure 5.9: Mean durations (ms) of Indonesian vowels preceding intervocalic stops and nasals vs. NC clusters, as produced by the bilingual Javanese/Indonesian speakers

The results show that the differences in durations of vowels preceding a stop (regardless of voicing), preceding a nasal, and preceding a NC cluster (again, regardless of the stop voicing) are very small.

Needless to say that these differences are not statistically significant. All else being equal, these results suggest that in each case, the consonant following the penultimate vowel, whether a single stop, a nasal, or a NC cluster, is not in coda position.

Comparing the durations of the penultimate vowels in the Indonesian of the bilingual speakers with those in the Indonesian of the monolingual speakers and with those in Javanese, they all exhibit a similar pattern whereby the durations of the penultimate vowels preceding an intervocalic nasal and preceding a NC cluster are comparable. This is interesting, considering the phonological pattern of NC cluster in Indonesian, which seems to suggest that the nasal portion of the NC cluster is in coda position.

These results also show that the durations of vowels preceding a voiceless stop are comparable to the durations of those preceding a voiced one. As discussed previously in Chapter 3, for the bilingual Javanese/ Indonesian speakers, Indonesian voiced stops are acoustically voiceless; there is no voice bar during the closure of these voiced stops. So, the penultimate vowels here precede stops that are essentially voiceless in their acoustic realization in both cases, and this is manifested in their durations. In contrast, for the monolingual Indonesian speakers, the durations of vowels preceding the stops reflect the voicing of the following consonant in that they tend to be shorter preceding a voiceless stop and longer preceding a voiced one (as shown earlier in Figure 5.6).

I discuss next the measurements of H1-A1 values of Indonesian penultimate vowels. The results are presented in Figure 5.10.

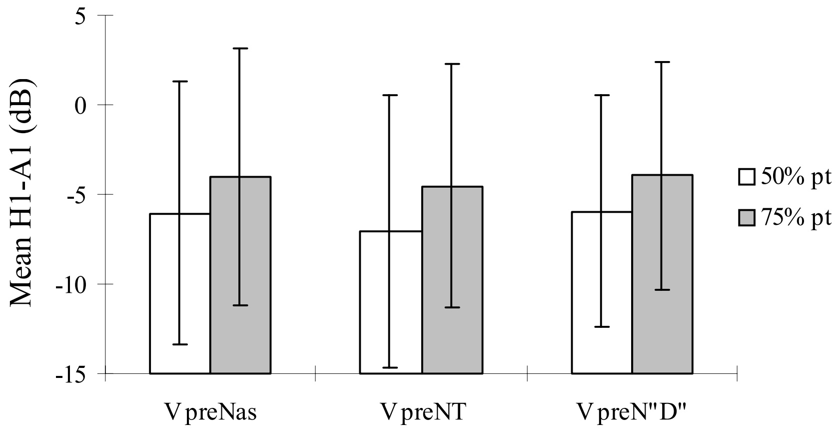


Figure 5.10: Mean H1-A1 values (in dB) of Indonesian vowels preceding intervocalic nasals vs. homorganic nasals in NC clusters, as produced by the bilingual Javanese/Indonesian speakers

The differences of H1-A1 values for the vowels at the 50% point preceding the stops are comparable. They are similar preceding the nasals, with 1 dB difference between V-preN and V-preNT. At the 75% point, these differences are similar for all vowels except for V-preT, of which the H1-A1 value is 2 dB smaller than that of the other vowels. Statistically, these differences are not significant for either point, as indicated by the high degree of overlap of the standard deviation bars.

These results suggest that, in the Indonesian of the bilingual speakers, F1 bandwidth is similar for vowels preceding an intervocalic nasal and preceding NC clusters, indicating that vowels are no more nasalized preceding the intervocalic nasal than preceding NC clusters. Comparing the H1-A1 values for the Indonesian penultimate vowels, the values for the bilingual speakers are greater than for monolinguals. In fact, the H1-A1 values in the Indonesian for the bilingual speakers are similar to the values in the Javanese for these bilingual speakers. This suggests that the Indonesian of the bilingual speakers is acoustically more similar to the Javanese of these speakers than to the Indonesian of the monolinguals.

Comparing these vowels at the 50% vs. 75% points, the H1-A1 values are greater for the latter suggesting that vowel bandwidth is wider at the point closer to the nasal. Statistically, the differences between the two points are not significant for any of the vowels.

I turn now to the durations of the medial consonants. The results are shown in Figure 5.11.

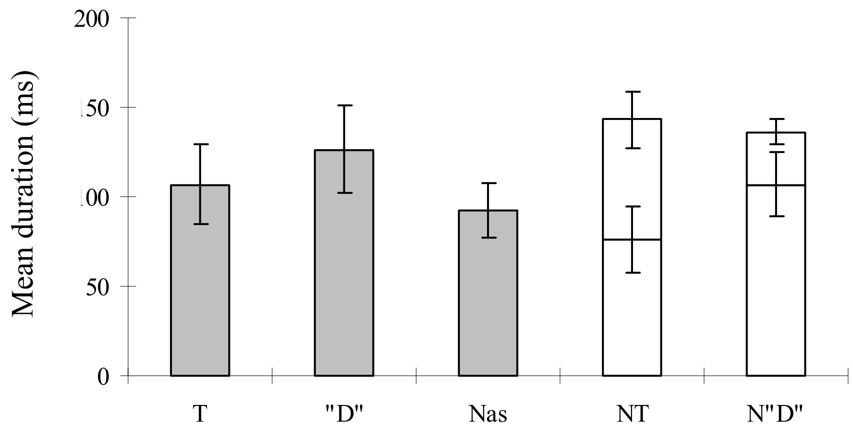


Figure 5.11: Mean durations (ms) of Indonesian intervocalic single stops and nasal vs. NC clusters, as produced by the bilingual Javanese/ Indonesian speakers

For these bilingual speakers, the durations of Indonesian voiced stops are greater by 16% than those of voiceless stops, in the intervocalic cases. This contradicts the general tendency whereby voiced stops tend to be longer in duration relative to voiceless ones. However, the Indonesian voiced stops are acoustically realized as voiceless by these speakers; this fact seems to be a contributing factor for the apparent contradiction in the stop durations.

The durations of the intervocalic nasals are smaller than either of the stops. They are also smaller than those of the homorganic nasals in N“D”, but greater than those in NT. The durations of both NC clusters are greater than those of the single consonants. The ratios of the duration differences are 1:1.3 for T:NT and 1:1.1 for “D”:N“D”. Statistically, the duration differences are significant for T vs. NT, but not for “D” vs. N“D”.

The durations of the Indonesian stops in NC clusters for the bilingual speakers are parallel to those for the monolingual speakers. The voiced stops in NC clusters are more than twice as long as the voiceless ones. There is a trade-off effect on the duration of consonants in the NC clusters, in that the homorganic nasals tend to be longer when preceding a voiced stop and they tend to be shorter when preceding a voiceless one. The durations of the homorganic nasals preceding a voiceless stop is 30% shorter than those preceding a voiced stop. The duration differences between the two homorganic nasals, between the stops in NC clusters, and between NT vs. ND do not reach statistic significance.

Overall, the acoustic measurements of the Indonesian vowels as produced by the bilingual speakers are similar to those by the monolingual speakers, in that these vowels are acoustically similar in terms of duration and F1 bandwidth, whether the following nasal is part of a NC cluster or not. Note that the acoustic results for the Indonesian vowels are similar to those for the Javanese vowels. Consequently, it is not possible to determine whether the acoustic results for the vowels in the Indonesian of the bilingual speakers reflect the Indonesian pattern or the Javanese pattern. Again, the durations of the medial stops, nasals and NC clusters are not indicative for the syllable affiliation of these medial consonant clusters in Indonesian.

In the following section, I summarize the results in § 5.4.1, § 5.4.2, and § 5.4.3, and then I discuss what the implications of these results on the relation between phonological phenomena and phonetic output, as well as directions for future research.

5.5 Discussion

In the previous section, we have seen the three types of acoustic measurement that might indicate the syllable affiliation of consonants, homorganic nasals in particular, following a vowel in the penult. It has been suggested that the durations of vowels and the F1 bandwidth of these vowels would show whether a following consonant is in coda or in onset position. As I have discussed earlier in this chapter, vowels have been found to be shorter in duration when they are in closed syllables (Maddieson, 1985) (even though there are clear exceptions, e.g. Letterman (1994), Ham (1998), among others), and vowels may be more nasalized when they precede a homorganic nasal in coda position than when they precede a nasal in onset position (Maddieson and Ladefoged, 1993) (though again, some studies (e.g. Cohn, 1990) do not show strong syllable affiliation effect).

In the case of NC clusters in Indonesian and Javanese, the working hypothesis is that based on the findings in a wide range of languages, relatively shorter vowel durations and wider F1 bandwidth would argue for medial consonants to be in coda position. The durations of these clusters may provide further insight as to whether they act as single complex units or as clusters of segments. If their durations are comparable to those of single intervocalic consonants, it would point to their being single complex units as has been argued for medial NC clusters in Fijian.

In Table 5.2, I summarize the results found in Javanese, and in Indonesian for the monolingual and bilingual speakers. Bold face indicates that the result is contrary to the prediction.

Table 5.2: Summary of acoustic measurements of Indonesian and Javanese penultimate vowels and NC clusters

	Javanese	Indonesian by monolingual speakers	Indonesian by speakers bilingual
Durations of penultimate vowels	• V-preNT ≈ V-preN/V-preT • V-preT$^{\text{fi}}$ ≈ V-preN/V-preND$^{\text{fi}}$	• **V-preNT ≈ V-preN/V-preT** • **V-preND ≈ V-preN/V-preD**	• V-preNT ≈ V-preN/V-preT • V-preN“D” ≈ V-preN/V-pre“D”
F1 bandwidth of penultimate vowels	• V-preN vs. V-preNT: 1 dB difference • **V-preN vs. V-preND$^{\text{fi}}$: 3 dB difference**	• **V-preN ≈ V-preNT** • **V-preN ≈ V-preND**	• V-preN vs. V-preNT: 1 dB difference • V-preN ≈ V-preN“D”
Durations of NC clusters	• **NC > T, T$^{\text{fi}}$, N**	• NC > T, D, N	• NC > T, “D”, N

Interpreting these results proves to be far from straightforward. By the durations of the penultimate vowels alone, we would be forced to say that there is no difference between the Javanese tautosyllabic NC clusters and the Indonesian heterosyllabic ones, suggesting that they are all in onset position. There are two possibilities that one may consider. First, it could be the case that Javanese vowels in penultimate syllable have similar duration whether the following consonant is single or a cluster (other than NC). However, as discussed earlier, Javanese penultimate vowels do undergo shortening preceding medial non-NC consonant clusters.

Second, one may also consider the possibility that vowels in Indonesian do not undergo shortening preceding a nasal in coda position. However, an acoustic study of Indonesian vowels (Adisasmito-Smith, 1998) shows that vowels preceding nasals in coda position are subject to vowel shortening. In this study, the durations of vowels preceding a morpheme boundary in cases like *raga+mu* 'your body' vs. *ragam+mu* 'your style' are compared. In addition, the durations of vowels preceding a word boundary in cases like *kala + manis* 'sweet time' vs. *kalam + manis* 'sweet word' are also compared. The findings show that the final vowels in *ragam* of *ragam+mu* and in *kalam* of *kalam + manis* are about 20% shorter than the final vowels in *raga* of *raga+mu* and in *kala* of *kala + manis*.

Given these possibilities, there are four questions that follow, each of which as discussed in the following paragraphs. First, is the claim regarding the phonological differences in Indonesian and Javanese accurate? Second, are the observed phonological differences manifested in the phonetics for the case at hand? Third, do tautosyllabic NC clusters in Javanese form a complex unit or do they remain a cluster? Fourth, are there other acoustic measurements that quantify nasal effect on vowels, which may be more sensitive to detect different syllable status of the following nasal?

With respect to the question as to whether the phonological observations made about NC clusters in Indonesian are accurate, given the synchronic evidence it would seem ad hoc to claim that these clusters are tautosyllabic. As discussed previously, the lack of initial NC clusters in Indonesian leads to the conclusion that NC clusters in this language are heterosyllabic. There are two possible venues to look into this question, by observing the patterns in languages that are closely related to Indonesian, namely Javanese and Standard Malay.

With respect to Javanese, since Indonesian and Javanese are genetically closely related, it is possible that NC clusters in Indonesian are tautosyllabic, despite the fact that phonological evidence is lacking. This would account for the similar acoustic patterns that the two languages show. However, this is not that strong a conclusion because of lack of evidence and the fact that tautosyllabic NC clusters appear to be not that common in Austronesian languages. Javanese and several languages in Eastern Indonesia are among the Austronesian languages known to have tautosyllabic NCs (Wolff, p.c), although it is noteworthy that some dialects of Malay have also been found to have tautosyllabic NCs (e.g. Gil, 2002).

Based on impressionistic observations, Teoh (1988) and Onn (1980) claim that vowels in Standard Malay and Johore Malay dialects, respectively, undergo lengthening preceding a NC cluster, as illustrated in the set of examples in (21).

(21) /bimbaŋ/→ [biːmbaŋ] 'fear'
/mandi/ → [maːndi] 'bathe'
/kunči/ → [kuːɲči] 'key'
/baŋga/ → [baːŋgə] 'proud'

According to Teoh, medial NC clusters are heterosyllabic. No account is given as to why this lengthening occurs. Lengthening of vowels preceding a nasal + stop cluster is common in many Bantu languages (e.g. Hubbard, 1995), argued to be due to the nasal giving up its timing unit to the preceding vowel as the nasal and the following stop form a complex unit, namely a prenasalized stop (e.g. Clements, 1986). To take a position opposite to Teoh's, it is possible that the NC clusters in Malay are actually in onset position and this results in the impressionistic vowel lengthening. In either case, if the observation of the lengthening is correct, one would be able to carry out an acoustic examination which would show that the durations of vowels are comparable preceding a NC cluster vs. preceding other single consonants. No acoustic data of Standard Malay is available.

If this lengthening is a characteristic shared by several historically related languages, Indonesian may exhibit a shared phenomenon with Standard Malay. Note, however, that it is possible that Indonesian penultimate vowels preceding medial NC clusters may in fact not undergo lengthening, rather they just do not undergo shortening. So far, there are only a few acoustic investigations carried out on languages in the region. Examinations of these languages may provide further insight.

Data from "non-traditional" use of a language, e.g. language game, secret language, etc. may provide insight into the distribution of sounds and their syllabification in a language. A language game in Minangkabau

Malay has a rule of taking the final syllable in a word and moving it to the front. The syllabification of a medial NC cluster is evident from whether the homorganic nasal and the stop remain together in the end result. The following data are cited from Gil (2002).

(22) *Data from a language game in Minangkabau Malay*

input word		Padang dialect	Jambi dialect
mintaʔ	‘request’	ntakmi	takmin
σ1 - σ2		σ2 - σ1	σ2 - σ1

For a speaker from Jambi, both the nasal and stop are moved to the beginning of the word. In contrast, for a speaker from Padang, the result of moving the syllable to the front is that the homorganic nasal from the input word stays postvocalic, while the stop is moved to the beginning of the word. This suggests that the medial NC cluster in the Padang dialect of Minangkabau Malay is tautosyllabic and in the Jambi dialect, it is heterosyllabic. It would be interesting to see whether acoustic differences correlate with this phonological difference in these dialects.

I further compare Indonesian with another closely related language, Sundanese. Sundanese is a language with strong phonological carry over nasalization (e.g. Cohn, 1990). Some impressionistic observations of Indonesian suggest a similar pattern. If this is the case, we would not expect to see much anticipatory nasalization beyond coarticulation. Consequently, the investigation to determine the syllable affiliation of post-vocalic nasals in Indonesian, based on the degree of nasalization on the preceding vowel, would not be fruitful. An area of future investigation would be the examination of nasal airflow data.

To address the second question, it is possible that a certain aspect of phonological structures is not reflected in their phonetic realization, as suggested by Ladefoged and Maddieson (1986). The acoustic durations and F1 bandwidth measurements of Indonesian penultimate vowels preceding NC clusters and the acoustic durations of these clusters definitely do not always agree with the phonological observations. In English, wherein a medial NC cluster is heterosyllabic, no appreciable differences are found in the durations of vowels preceding a NC clusters vs. preceding a C (e.g. Vatikiotis-Bateson, 1984). Aerodynamic data of English vowels preceding medial nasals (Cohn, 1990) suggest that vowels undergo nasalization preceding an intervocalic nasal and preceding a medial NC cluster. The degrees to which the vowels are affected seem to be similar, which means that nasals in coda position do not have more effect than nasals in onset position. The Indonesian and Javanese vowel cases and those of English vowels would be evidence supporting Ladefoged and Maddieson's claim.

As discussed earlier, the durations of medial NC clusters and those of the preceding vowels in Fijian support the claim that medial NC clusters in this language are in onset position, given the findings where vowels preceding a NC cluster or a single consonant are comparable in duration; in addition, these clusters are argued to form a complex unit since their durations are comparable to those of other single consonants (Maddieson, 1989). On the other hand, acoustic findings in Italian suggest that vowels are shorter in duration preceding heterosyllabic medial NC clusters than preceding intervocalic nasals (Farnetani and Kori, 1986; Smith, 1992).

Given the findings in Indonesian, Javanese and English on the one hand, and Fijian and Italian on the other, it may be the case that Ladefoged and Maddieson's claim is subject to language-specific idiosyncrasy. As a more general issue, this would also mean that certain phonological structures may or may not be manifested phonetically, and individual language may vary in terms of which structures do or do not find their expression in the phonetics.

With respect to the issue regarding syllable affiliation, tautosyllabic NC clusters in a range of languages have been argued to form a complex unit, i.e. a prenasalized stop, based on the phonotactic constraints of the language, such as strict CV syllable structure (e.g. Fijian), vowel alternation (e.g. Javanese), etc. In addition, treating tautosyllabic NC clusters as a prenasalized stop is a solution to the problem of violating the sonority sequencing principle commonly observed across languages. Acoustically, we have seen that the durations of Javanese tautosyllabic NC clusters are greater than those of single stops or nasals. In contrast, Fijian tautosyllabic NCs, stops and lateral have a similar timing pattern, suggesting that Fijian NCs behave as a unit, i.e. a prenasalized stop. It seems that we cannot necessarily extend this claim to the Javanese cases, since their timing pattern does not support it. The case in LuGanda (Maddieson and Ladefoged, 1993) is parallel to that in Javanese. This problem suggests that in terms of timing organization, a tautosyllabic NCs do not always behave as a (complex) unit. Maddieson and Ladefoged address this issue by suggesting two possible strategies for languages where tautosyllabic NCs form a complex unit. These strategies are schematized in (23).

(23) *Schema of the timing organization of tautosyllabic NC*

```
a.          C                        b.          C
      ||__________||                       ||__________||

        N     C                              N           C
      ||______||___||                      ||________||______||
```

Languages may be organized in such a way that the timing pattern of NCs (assumed to be prenasalized stops) is "compressed" to match that of other single consonants, as shown in (21a). Fijian would be an example for the case in (21a). However, other languages may not be constrained in this way; instead, they may impose a limit on the amount of compression, and consequently the NCs are longer than single consonants, as shown in (21b). Javanese and LuGanda would exemplify this case.

Returning to the subject of vowel shortening in closed syllables, most of the data presented by Maddieson (1985) are either vowels preceding geminate vs. single consonants, or vowels in monosyllabic words of the form CVNC, or in final syllables (except Assamese). This is not to say that Indonesian vowels do not undergo shortening preceding a nasal in coda position, since they do, as mentioned earlier. What is different in the present study is the fact that these vowels precede a homorganic nasal, rather than a nasal already specified for place of articulation; and somehow these vowels do not undergo shortening in this environment. It may be that in some languages, a vowel interacts with the following homorganic nasal in coda position such that their timing pattern is different from that of other VC sequences. This, however, does not apply to Italian where vowels do undergo shortening preceding heterosyllabic NC cluster.

The investigation into whether a medial homorganic nasal is in coda or onset position here has focused on two particular acoustic characteristics of the preceding vowel, namely durations and F1 bandwidth. It may be the case that these acoustic features are not sufficient to detect possible anticipatory nasal effects in Indonesian vowels. Chen (1997) proposes calculations that measure the acoustic effect of nasal on a vowel, based on evidence from English and French. This method has also been used to quantify the anticipatory nasal effect on vowels in Standard Chinese (Chen, 2000). In her technique, the amplitude values of extra peaks that are present due to nasal effect are compared with the amplitude of the first formant. The location of one of the extra peaks is between the first and second formants, and the other one is below first formant. Testing nasal effect on Indonesian vowels preceding homorganic vs. non-homorganic nasals using this technique is in progress. Note that it is also possible that durations and F1 bandwidth are not the only cues to syllabification, or that intervocalic syllabification is not always definitive and that it might be ambiguous.

In conclusion, the results in this chapter either support the conclusion that the NC clusters in Indonesian are not heterosyllabic, or that such syllable differences hypothesized for the Indonesian of the bilingual speakers are not reflected in the phonetics. Closer examination of such phonological pattern and their phonetic realization in a wider range of languages will hopefully shed more light on this question.

CHAPTER SIX:
CONCLUSIONS

When different peoples come in contact, so do their languages. During the interaction among the speakers of different languages, it is common for one language to borrow certain linguistic features from another language. Linguistic borrowing may occur in different domains of the language. In the present study, we investigated the linguistic borrowing phenomenon at the level of phonology and phonetics, that is the sound patterning and their realizations, taking Indonesian and Javanese as the case of study. Particularly examined here are vowel alternation (studied in Chapter 3), voice quality (studied in Chapter 4), and syllable structure (studied in Chapter 5) in Javanese and in the Indonesian of the monolinguals and of the bilingual Javanese speakers. Impressionistically, these linguistic features in Javanese are manifested in the Indonesian of the bilingual Javanese speakers. There has been very little systematic phonetic work carried out on Indonesian or Javanese. In order to verify these impressionistic observations and test the specific hypotheses, we need to study the phonetic realizations of these linguistic features in Javanese and in the Indonesian of the monolinguals and the bilingual speakers.

I summarize the overall results in the phonetic study in § 6.1. Then I discuss the issues of the correlation between the degree of Javanese influence on Indonesian and speakers' attitude in § 6.2, and the interface of phonetics and phonology and its implication to languages in contact in § 6.3. In § 6.4, I consider future research, and I briefly conclude in § 6.5.

6.1 Overall results

As outlined earlier in Chapter 1, Javanese and Indonesian differ systematically in the patterning of (1) vowel alternation governed by syllable structure, (2) stop contrast of breathy vs. clear (Javanese) and voiced vs. voiceless (Indonesian), and (3) syllabification of root-medial NC as tautosyllabic (Javanese) or heterosyllabic (Indonesian), observable by way of vowel alternation.

With respect to vowel alternation, there are several phonological differences between Javanese and Indonesian. Impressionistically, all vowels in Javanese lower in final CVC syllables; the lowered high vowels [ɪ, ʊ] are as low as the non-lowered mid vowels [e, o], and the lowered mid back vowel and the raised low vowel are impressionistically similar. In addition, vowel harmony occurs in all vowels in the penultimate syllable in the Eastern dialect of Javanese and it occurs in the mid and low vowels in the Central dialect. In Indonesian, vowel alternation occurs in the mid vowels, which lower in final CVC syllables, and vowel harmony occurs in the mid vowels in the penultimate syllable. The acoustic results for Javanese as produced by the speakers from Central and East Java are consisted with the impressionistic observations. The results for Indonesian were seen to be less straightforward. For the monolingual speakers, high vowels in final CVC syllables and those in penultimate syllables preceding a CVC syllable lower, even though they are still distinct from the non lowered mid vowels. In the Indonesian of the bilingual speakers from both Central and Eastern Java, the high vowels lower and overlap with the non lowered mid vowels, parallel to the acoustic results for Javanese high vowels as produced by these bilingual speakers. The results also show that vowel harmony for the Indonesian high vowels is acoustically realized only in the front vowel but not in the back one, for the Eastern Javanese bilingual speakers. In the Indonesian of the monolinguals and the bilinguals from Central Java, vowel harmony is realized in the mid vowels, consistent with the impressionistic observations.

As discussed in the voice quality study, Javanese stops are contrastive with respect to breathy vs. clear, while Indonesian stops are either voiced or voiceless. Impressionistically, bilingual Javanese speakers transfer the breathy/clear contrast in Javanese to Indonesian. Acoustic measurements of F0, spectral tilt, F1 bandwidth, and noise intensity indicate that the stops of the Indonesian of the bilingual speakers from East and Central Java exhibit the breathy/clear contrast of Javanese stops, realized and measured in the following vowel. For these bilingual speakers, the Indonesian voiced stops are voiceless and the following vowel is breathy, and the Indonesian voiceless stops are voiceless, with the following vowel being modal/non-breathy. Interestingly, the acoustic results also show that, for one of the two female monolingual speakers of Indonesian, vowels following the Indonesian voiced stops are breathy while the voicing during the stop closure is maintained. I suggest that the source for this breathiness may be due to physiological (i.e. a female speaker) or social reasons.

The acoustic results for the syllabification of NC clusters are not as expected. Given the facts about vowel alternation, root-medial NC clusters in Javanese are argued to be tautosyllabic; in 'Standard' Indonesian, they are widely assumed to be heterosyllabic. The duration measurements of Javanese medial NC clusters and the preceding vowels suggest the tautosyllabic status of these root-medial clusters. This result is mirrored in the Indonesian of the bilingual speakers. However, the duration measurements of medial NC clusters and the preceding vowels in the Indonesian of the monolinguals suggest that these medial clusters are also tautosyllabic. This result may indicate that in the Indonesian of these monolinguals, medial NC clusters are tautosyllabic; it is also possible that this is a case whereby a phonological pattern is not necessarily realized in the phonetics.

In brief, the results from the acoustic study indicate that two out of three cases, i.e. vowel alternation and voice quality, strongly support the hypotheses that Javanese phonology is realized in the Indonesian of the bilingual speakers. The third case, syllable structure, is not inconsistent with the hypothesis; it just does not support the widely held phonological analysis in Indonesian. On that account, there is indeed a strong reflection of phonological system of Javanese in the Indonesian of the bilingual Javanese speakers, which is quite distinct from the observed patterns for the monolingual Indonesians.

The acoustic results in this study brought about other related issues. The first issue is related to the correlation between the degree of influence of Javanese in the Indonesian of the bilingual speakers and the attitude of these speakers towards either or both languages, discussed in § 6.2. The second issue concerns with the interface of phonetics and phonology and its implications for languages in contact, discussed in § 6.3.

6.2 Speakers' attitude and degree of Javanese influence on Indonesian

In a multilingual situation, the phenomena of speakers' attitude towards the languages they use to communicate and speaking with an 'accent' are among the prevalent issues. Studies on language attitudes commonly find that bilingual speakers prefer one language over another (e.g. studies in Shuy and Fasold, 1973; Ryan et al., 1982; van Coetsem, 1988; Romaine, 1995; Coupland et al., 1999; a review by Burns et al., 2001, and others). The preference for one language over the other may result from social prestige, language dominance, functionality, etc. Another issue in multilingualism is speaking with an 'accent' which occurs when a multi-/bilingual speaker applies the grammar (e.g. phonology) of one language onto another (see, e.g., van Coetsem, 1988). In many cases, the issue of language preference may coexist with the issue of speaking with an accent. For example, Romaine (1995) finds that a West Indian was judged more favorably when speaking English with a working-class White accent than with a West Indian one. With respect to Javanese, it is generally perceived as a language of high prestige, and thus speaking Indonesian with a Javanese accent is not always viewed unfavorably. In fact, it seems acceptable in certain circles, such as the government, etc.

Similar phenomena are reflected in the interviews, conducted after the recording, with the consultants in the present study. Some of those interviewed expressed no preference between speaking Javanese or Indonesian, but some others seemed to favor the use of one language or the other. In addition, several of the recorded speakers expressed 'concerns' about how their Indonesian with the Javanese accent would sound in the recording. This leaning towards one language or the other may determine the amount of influence of Javanese in the Indonesian of the bilingual speakers, and consequently the kind of linguistic modification (or maintenance) performed during a speech event. The acoustic results in the voice quality study may showcase the correlation between a bilingual speaker's attitude towards Javanese and the amount of Javanese influence in their Indonesian.

As mentioned previously in Chapter 2, the three speakers whose speech is analyzed in the voice quality study have lived in the US for over five years, ranging between 8 and 15 years. One may suppose that given the length of time of their stay in the US, these speakers would lose the breathy characteristic of Javanese stops. However, their profession as teachers of Javanese music and performers may be a factor in their maintaining the breathy vs. clear contrast of Javanese stops. While the results in this study are affirmative of the Javanese influence on the Indonesian of the bilingual speakers, one also needs to be aware that the attitude of Javanese speakers towards the breathy characteristic of their language ranges from considering it as unique to a stigma. Consequently, some Javanese bilingual speakers may consciously attempt to substitute the stop contrast from breathy vs. clear to voiced vs. voiceless when they speak Indonesian, as in the case of the radio broadcasters from Central Java, mentioned earlier in the Introduction. Note that speakers' attitude regarding the languages they employ might be quite subconscious. The speech of the Javanese/Indonesian bilingual speakers who attempt to modify their voice quality would be an interesting subject of study. In addition, one may carry out a perceptual study to examine the bilingual speakers' level of awareness of their attitude towards their languages.

6.3 Phonetics/Phonology interface and languages in contact

In this section, I discuss the importance of phonetics/phonology interface in the study of language contact. First, I review the implications of the acoustic results for Javanese and Indonesian.

As discussed in § 6.1, acoustic results in this study indicate that systematic differences between Javanese and Indonesian are realized in the phonetics, particularly with respect to vowel alternation and voice quality of stops. High vowels in Javanese lower in final closed syllables, to the point that their height overlaps with that of the mid vowels in final open syllables. In Indonesian, while the high vowels lower in final closed syllables, their height and that of the mid vowels in open final syllables are still distinct. Stops in Javanese are both voiceless and are either breathy or clear, having their contrast acoustically realized on the following vowel. Indonesian stops are either voiced or voiceless. In addition, the acoustic results allow us to observe that certain linguistic features in one language may 'fail' to be realized in the other language, which might be due to speakers' (conscious/unconscious) decision, as the asymmetrical vowel harmony in the Indonesian of the bilingual speakers from East Java may illustrate. Acoustic data may also show subtle differences in the manifestation of linguistic imposition, which otherwise would not be discernible. For example, the study here shows that some bilingual speakers may use different acoustic cues to realize breathiness in Javanese vs. in Indonesian.

The study carried out in this dissertation is concerned with the interaction between phonology and phonetics, with the ways in which discrete units of phonology are mapped to the continuous patterns of phonetics. Different studies have shown that phonological patterns may or may not be realized phonetically, and that phonetic differences are not always due to phonological differences. The investigation in this work highlights the ways in which phonological patterns in one language are manifested (or not) in another, taking Indonesian and Javanese as a test case. The contact between Indonesian and Javanese is manifested in the form of the realization of Javanese linguistic features in the Indonesian of the bilingual Javanese/Indonesian speakers.

As discussed in the Introduction, many observations regarding the realization of linguistic feature/s in the case of language contact are impressionistic in nature. These observations alone are not sufficient in providing facts about linguistic imposition of one language on another, because there may be differences in, for example, sound system at different levels. Both the observed phonological patterns in the languages involved and the phonetic manifestations (analyzed here acoustically) of language interaction are needed to show whether the linguistic influence occurs in the case of language contact, and they would also show the ways in which this influence is acoustically achieved. Thus, they would allow us to determine whether or not the impressionistic observations take place and to eliminate inaccurate claims due to the influence of the observers' own language in their interpretation of their linguistic data. The acoustic results indicate that phonological realizations studied with acoustic methods are quite reliable for the linguistic features under study here, with the one exception of the syllabification in Indonesian and Javanese.

Given the relationship between phonetics and phonology, acoustic findings may be divided into four logical categories, depending on whether or not acoustic differences bear phonological significance and whether or not the phonological patterns are manifested acoustically. These four categories are presented in Table 6.1.

Table 6.3: Phonetics and phonology interface

	acoustic differences	phonological differences
Category 1	yes	yes
Category 2	yes	no
Category 3	no	yes
Category 4	no	no

In *Category 1* are cases where the observed acoustic differences are due to phonological differences. In *Category 2* are cases where the source of acoustic differences is not phonological. *Category 3* includes cases where certain phonological patterns are not realized in the phonetics. In *Category 4* are cases where compared sounds bear no acoustic differences or phonological differences. Presumably, the cases in *Category 4* would be those sounds that are acoustically similar and outside the realm of phonology, and thus are beyond our topic of discussion here.

In the present study, some of the acoustic results fall under *Category 1*, wherein the observed acoustic differences are due to phonological differences, illustrated as follows. The impressionistic observations regarding Javanese vowels that are supported by the acoustic results are (1) the lowering of high and mid vowels in final CVC syllables as compared to these vowels in final CV syllables, (2) the impressionistic similarity of the lowered high vowels and the non-lowered mid vowels, and (3) the impressionistic similarity of the low vowel /a/ in final CV syllable and the mid vowel /o/ in final CVC syllable. The acoustic results also support the impressionistic observations of mid vowel lowering in final CVC syllables, in the Indonesian of the monolinguals. For vowels in the Indonesian of the bilingual speakers, the acoustic results support the impressionistic observations of (1) the lowering of high and mid vowels in final CVC syllables as compared to these vowels in final CV syllables for speakers from East and Central Java, (2) the impressionistic similarity of the lowered high vowels and the non-lowered mid vowels for the speakers from Central Java, (3) the impressionistic similarity of the lowered front high vowel and the non-lowered front mid vowel for the speakers from East Java. Additionally, the impressionistic vowel harmony that occurs to vowels in the penult in Javanese and Indonesian is realized acoustically for (1) mid and low vowels in Javanese for the Central Javanese speakers, (2) front high, mid, and low vowels in Javanese for the Eastern Javanese speakers, (3) mid vowels in Indonesian for the monolingual and the bilingual speakers, (4) front high vowels in Indonesian for bilingual speakers from East Java.

These results would support the following hypotheses: (1) Javanese high and mid vowels are tense in final CV syllables and lax in final CVC syllables, (2) the Javanese low vowel in final CV syllables and the mid back vowel in final CVC syllables are realized as [ɔ], (3) the Indonesian mid vowels in final syllables also undergo the tense/lax alternation governed by the syllable structure, (4) the tense/lax alternation of Javanese vowels in final syllables is realized in the Indonesian of the bilingual speakers from both the Central and the East regions, (5) vowel harmony applies to non-high vowels in Javanese of both regions, (6) vowel harmony may apply to high vowels in Eastern Javanese, though we are certain only for the front vowel, and (7) vowel harmony applies to the mid vowels in Indonesian.

The impressionistic differences of stops in Javanese vs. in Indonesian are also supported by the acoustic results, in that stops in Javanese are either breathy or clear, and in the Indonesian of the monolinguals they are either voiced or voiceless. In addition, voiced stops in the Indonesian of the bilinguals are acoustically breathy and voiceless stops are realized as clear. These results would support the hypothesis that (1) Javanese stops are contrastive with respect to breathiness, (2) Indonesian stops are contrastive with respect to voicing, and (3) the voice quality of Javanese stops is transferred to the stops in the Indonesian of the bilingual speakers.

In *Category 2* is the case where the acoustic variation is due to the phonetic properties of segments, and thus, does not correlate with a phonological pattern. The lowering of final high vowels in CVC syllables in the Indonesian of the monolingual speakers exemplifies this case. Van Zanten (1989) finds this to be the case in the Indonesian of the monolinguals and of Sundanese and Toba Batak bilingual speakers. In these cases, the presence of a consonant in coda position raises the first formant values of the preceding high vowel, and thus lowers it in the acoustic space. The results in the perceptual study conducted by van

Zanten (1989) indicate that both lowered and non lowered high vowels, i.e. high vowels in final CVC and final CV syllables, respectively, are identified as either /i/ or /u/. This suggests that high vowel lowering in the Indonesian of the monolingual speakers and of the bilingual speakers of Sundanese and of Toba Batak is at the level of coarticulation, but has not been phonologized.

In *Category 3* are cases where certain phonological patterns are not systematically realized in the phonetics. There are two cases in the acoustic results in this study that exemplify this category: vowel harmony in the Indonesian of the Eastern Javanese speakers and the syllabification of root-medial NC clusters in Indonesian. The sources of the disjunction between phonetics and phonology illustrated by the acoustic results here are different. In the vowel harmony case, the disjunction is due to extra-linguistic factor, and in the NC cluster case, it seem to be due to the phonetic properties of the cluster. As mentioned previously, Indonesian high vowels impressionistically undergo vowel harmony for the Eastern Javanese speakers. However, the acoustic results indicate that only /i/ undergo vowel harmony in the Indonesian of these speakers. Thus, the hypothesis that vowel harmony in Eastern Javanese, particularly applying to the high vowels, is only partially supported by the acoustic results.

In the case of the syllabification of root-medial NC clusters in Indonesian, we hypothesize that the nasal portion of NC clusters is in coda position, in keeping with the syllabification of other root-medial clusters in the language and with the fact that Indonesian NC clusters do not occur in the root-initial position. We would expect to see this acoustically manifested in the Indonesian of the monolinguals. However, the acoustic results do not support this hypothesis, since the durations of the penultimate vowel, expected to be shorter in closed syllables, are similar whether it is followed by an intervocalic nasal in onset position or by a nasal (of NC clusters) in coda position. A similar result is found in English (Vatikiotis-Bateson, 1984). It is possible that the phonetic properties of nasals are such that they affect the duration of preceding vowels.

As discussed in the Introduction, many observations regarding the realization of linguistic feature/s in the case of language contact are impressionistic in nature. These observations alone would not be sufficient to provide facts about linguistic imposition of one language on another. Both the observed phonological patterns in the languages involved and the acoustic data of the manifestations of language interaction are needed to show whether the linguistic influence occurs in the case of language contact, and they would also show the ways in which this influence is acoustically achieved. Thus, they would allow us to determine whether or not the impressionistic observations take place and to eliminate inaccurate claims due to the influence of the observers' own language in their interpretation of their linguistic data.

In summary, this study as a whole examines the relationship of phonology and phonetics by investigating the manifestation of certain linguistic features in one language into another, as two languages come in contact, taking Javanese and Indonesian as the case study.

The linguistic features examined in this study to investigate the influence of Javanese on Indonesian are by no means the only features by which the influence is manifested. However, these features are chosen since they are impressionistically salient. Further study is needed to determine to what extent Javanese influence on Indonesian is realized. We have also seen issues that emerge from the examination of vowel alternation, breathiness, and NC clusters. I lay out these issues and related future research in the next section.

6.4 Future research

Each of the studies carried out here raised important areas for further research. I now turn to discuss three particular future studies: additional acoustic studies (§ 6.4.1), perceptual studies that can validate the acoustic findings and their effects (§ 6.4.2), and similar studies of other contact situations (§ 6.4.3).

6.4.1 Further acoustic studies

The acoustic study of Javanese and Indonesian carried out here is only the beginning of a larger inquiry into the study of sounds and their acoustic realization in Javanese, Indonesian, and other closely related languages. This area of study has largely been under-investigated. I lay out in the following, additional acoustic studies that expand what have been examined here: vowel alternation, voice quality, and NC cluster syllabification.

The study on vowel alternation here focuses on vowels in open vs. closed syllables in root-final position. As discussed previously, high and mid vowels in Javanese lower and centralize in a closed final syllable. In addition, the low vowel /a/ in an open final syllable is realized as [ɔ], similar to the realization of the mid back vowel /o/ in a closed final syllable. There are other cases in which phonological processes render different vowels to be impressionistically similar. An example for such a case is when two underlying vowels become adjacent at the root + suffix boundary. This is illustrated in the set of examples in (1). The circumfix /kə/ + /ən/ indicates superlative quality, when the root is adjectival.

(1) *Vowel coalescence in Javanese*

a.	/kə + panas + ən/	→ [kəpanasən]	'too hot'
	/kə + duwur + ən/	→ [kəduwurən]	'too tall'
b.	/kə + bəŋi + ən/	→ [kəbəŋɛn]	'too late (at night)'
	/kə + gəde + ən/	→ [kəgədɛn]	'too big'
c.	/kə + ləmu + ən/	→ [kələmɔn]	'too fat'
	/kə + ǰəro + ən/	→ [kəǰərɔn]	'too deep'
d.	/kə + tʱawa + ən/	→ [kətʱawan]	'too long'

Based on impressionistic observations, when an adjectival root ends in a consonant and is followed by the vowel-initial superlative suffix, the vowel surfaces as a schwa, as shown in (a). When the root ends in a vowel, the two vowels coalesce. Root-final front (non-low) vowels /i, e/ are realized as the lax mid front vowel, [ɛ], and root-final back (non-low) vowels /u, o/ is realized as the lax mid back vowel, [ɔ], as shown in (b-c). When root-final vowel is /a/, the vowel of the suffix is deleted, as shown in (d). Parallel to the acoustic study in the vowel chapter, it would be interesting to compare these coalesced vowels with the underlying mid vowels in closed final syllables. One may expect to find that the derived vowels due to coalescence and those due to syllable structure are acoustically similar. However, it is also possible that certain acoustic differences are maintained, since the derived vowels are the result of two different phonological processes.

In the vowel study, we see the unexpected acoustic result whereby the high vowels in the penultimate and final syllables lower slightly when the final syllable is CVC, in the Indonesian of the monolingual speakers. A greater number of monolingual speakers of Indonesian is necessary to determine whether the lowering of high vowels in both the penultimate and final syllables is a phonetic process due to coarticulation, or whether it is a phonological process due to syllable structure and vowel harmony. Comparisons with other dialects of Indonesian, such as those spoken in Central and South Sumatra, may increase our understanding of the nature of vowel alternation in Indonesian.

In the study of voice quality, we have seen earlier the different measurements of the acoustic correlates of breathiness, realized on the vowel following the breathy stops in Javanese. These measurements are fundamental frequency, spectral tilt, bandwidth of first formant, and intensity of noise. These measurements are also carried out for the post-stop vowels in Indonesian, in which stops are either voiced or voiceless. The findings for the vowels in Indonesian indicate that vowels following a voiced stop tend to exhibit greater spectral tilt than those following a voiceless stop. This tendency has also been observed in Xhosa (Jessen and Roux, 2002) and Ju|'hoansi (Miller-Ockhuizen forthcoming). In these two languages, vowel spectral tilt (H1-H2) has the tendency to be greater following voiced clicks than following their voiceless counterpart. So far, there is no available acoustic data on the effect of (non-click) stop voicing on spectral tilt. A study on voiced vs. voiceless stops in Indonesian and in other languages, and their effect on vowel spectral tilt would add to our understanding of the ways in which consonants may affect the acoustic properties of the surrounding vowels.

The acoustic results in the voice quality study also indicate that a female monolingual speaker of Indonesian tend to be breathy. In Indonesian, stops are characterized as being voiced or voiceless, rather than being breathy or modal. Previous studies have shown that female speakers have the tendency to be breathier than male speakers. The origin of the breathiness for female speakers has been argued to be due to social (e.g. Henton and Bladon, 1985; Klatt and Klatt, 1990, among others) or physiological reasons (e.g. Henton, 1987; Linville, 2001, and others). (See Chapter 4 for more detailed discussion.) Note that the consultants in voice quality and gender difference studies are native speakers of English or Swedish (e.g. Karlsson, 1994). A study involving female consultants who are native speakers of a non-Indo European language, in which breathiness is not contrastive, may provide further insight to investigations of the effect of gender difference on degrees of breathiness. In addition, if breathiness is a physiological effect, a study comparing female vs. male speakers in a language where breathiness is contrastive would indicate the ways in which the tendency for female speakers to be breathier than male speakers is acoustically realized.

A further development of the study on the voice quality of the speakers from Java is to include those who still reside in Java from both Central and East regions. The Javanese speakers in the voice quality study here are based on the speech of those who live outside the Javanese community in Indonesia for over five years. While the results here indicate that these speakers maintain the breathy quality of Javanese stops, examining Javanese speakers who experience less influence from other linguistic communities may serve as an insightful comparison.

As discussed in the Introduction, bilingual speakers from Central Java who are FM radio broadcasters attempt to modify their Indonesian in order to produce a 'Standard' variety. One linguistic variable that these broadcasters seem to try to convert is the breathy vs. clear contrast in their Indonesian to the voiced vs. voiceless contrast in the Indonesian of the monolingual speakers. Given the appropriate context, these speakers may be successful in the voice quality conversion. An acoustic study based on the speech of these bilingual radio broadcasters may reveal whether their goal of modifying their voice quality is achieved and to what extent.

We have seen in Chapter 5, that the widely held phonological analysis of root-medial NC clusters in Indonesian (i.e. heterosyllabic) is not supported by the acoustic results. Recall that Maddieson (1985) finds that vowels in a closed syllable tend to be shorter in duration than vowels in an open syllable (though, note the exception in Sinhala (Letterman, 1994) and in Hungarian (Ham, 1998)). We expected vowels preceding the nasal portion of a root-medial NC cluster in Indonesian to be shorter in duration than vowels preceding an intervocalic nasal; instead there is no appreciable difference in duration for the vowels preceding NC clusters vs. intervocalic nasals. This does not seem to be a unique case. Vowels preceding heterosyllabic root-medial NC clusters in English are no shorter than those preceding intervocalic nasals (Vatikiotis-Bateson, 1984). Further acoustic studies on the duration of vowels preceding heterosyllabic root-medial NC clusters vs. intervocalic nasals, as well as preceding other non-NC consonant clusters may enlighten us about the acoustic effect that nasals (intervocalic and part of a NC cluster) may have on the preceding vowel, and consequently the possible differences between NC vs. non-NC clusters.

The future studies laid out in this section, and other similar studies, especially on less commonly studied non Indo-European languages, would contribute to our understanding of possible sounds and sound patterns cross-linguistically.

6.4.2 Perceptual studies

I turn now to the discussion of future perceptual studies. Some of these proposed studies may be inspired by the acoustic results obtained in the present study, and some others by future acoustic studies in which a perceptual study would enhance our understanding of the subject of investigation.

The acoustic results in this study indicate that distinct phonemes may be impressionistically and acoustically similar (e.g. /i/ in final CVC vs. /e/ in final CV in Javanese) and the same phoneme may be impressionistically similar but acoustically different (e.g. /i/ in final CV vs. final CVC in the Indonesian of the monolinguals). In addition, as pointed out in Chapter 1, speakers seem (or claim) to be aware of some of the systemic differences between Javanese and Indonesian. The acoustic results and the speakers' awareness lead to the question of which cues that speakers use to recognize distinctions or similarities between the two languages. The findings in van Zanten's study (1989) indicate that the non-lowered mid vowels in the final syllable of the CeCe and CoCo tokens in the Indonesian of the Central Javanese speakers are misidentified by Eastern Javanese listeners as (lowered) high vowels. Further perceptual studies on Indonesian high vowels may determine (1) whether the lowered and non-lowered high vowels in the Indonesian of the monolinguals and the bilinguals from Central and East Java are identified as distinct by Indonesian listeners (monolinguals and bilinguals) from the respective language group, and (2) whether the lowered high vowels and the non-lowered mid vowels in the Indonesian of the bilingual speakers from Central and East Java regions are identified as similar by bilingual listeners from the respective regions.

In the voice quality study, the acoustic results indicate that one of the monolingual female speakers of Indonesian tends to be breathy. Comparing monolingual female speakers of Indonesian with the tendency to be breathy and bilingual female speakers of Indonesian/Javanese who transfer Javanese breathy/clear contrast into their Indonesian, one may ask listeners the identity of the female speakers, i.e. whether they are monolingual Indonesian speakers (e.g. from the city of Jakarta) or bilingual Indonesian speakers from Java (e.g. from the city of Solo). For cases of the Indonesian intervocalic voiced stops, listeners would very likely take the acoustic voicing (or the lack thereof) of stops as the cue to distinguish the two speaker groups. In cases of the Indonesian voiced stops in NC clusters, where the stops are acoustically voiced for both speaker groups, listeners would have to rely on a different set of cues (e.g. degree of breathiness) to correctly distinguish them, if indeed they perceive the difference.

As mentioned previously, speakers are aware of the ‘accented’ speech; in this study, it is Indonesian with Javanese accent. Some of the

Javanese speakers, especially those from East Java, indicated a feeling of uneasiness in speaking their dialect of Javanese, i.e. the Eastern dialect of Javanese, a dialect of lower prestige as compared to the Javanese dialect spoken in Central Java, in addition to speaking Indonesian characterized with breathiness (i.e. in opposition to the Indonesian of non-Javanese speakers). As a result, they may modify their production of the Indonesian tokens. The issue here is how this awareness can be examined, among the bilingual Eastern Javanese speakers as well as among other bilingual and monolingual speakers of Indonesian. In a perceptual study, one may assess the level of awareness and speakers' attitude by addressing questions such as whether Indonesian with a certain accent (e.g. with a Central Javanese vs. an Eastern Javanese accent) is beautiful, or coarse, or ungrammatical, etc., whether a speaker communicating in Indonesian with a certain accent sounds intelligent, or uneducated, or friendly, etc. In studies on language attitudes, researchers find that in Morocco, for example, French is judged as modern and Classical Arabic as rich and beautiful (Bentahila, 1983), that Welsh spoken in Cardiff (an urban community in Eastern Wales) is considered as harsh, ugly, or annoying (Coupland et al., 1999), etc. These are some of the characteristics that would identify speakers' attitude and stereotyped impressions toward a language. Ryan et al. (1982) and Burns et al. (2001), for example, provide a review for the ways in which information about speakers' attitude may be obtained, which could include the use of questionnaires, interviews, tape recordings, etc.

6.4.3 Contact language studies

The study carried out here emphasizes the interaction between Javanese and Indonesian. The effect of the contact is realized acoustically in the Indonesian of the bilingual Javanese speakers, as observed in two of the three linguistic variables examined here. The influence of one language on another in a language contact situation manifests in different aspects of the language. Previous acoustic studies have documented the effect of bilingualism on phonetic variables; for example, voice onset time (e.g. Major, 1992; Hazan and Boulakia, 1993; Khattab, 2000, among others), tone (e.g. Ho Dac, 1997; Wang, 2002, among others), vowel quality (e.g. Godinez and Maddieson, 1985; Anderson, 1999; Flege et al., 2003, among others), vowel length (e.g. Mack, 1982; McDonough and Austin-Garrison, 1994, among others), etc.

Thus, the study of the realization of Javanese sound pattern in the Indonesian of the bilingual Javanese speakers is by no means unique. However, there is only a handful of acoustic studies on the phenomenon of language contact in Indonesia, where more than 500 languages are spoken (e.g. van Zanten, 1989; Adisasmito-Smith, 1999b). Note also that there are only relatively a few acoustic studies on these mostly Austronesian languages (e.g. van Zanten, 1989; Laksman, 1994; Cohn and Lockwood, 1994; Adisasmito and Cohn, 1996; Cohn and Ham, 1998; Podesva, 1998; Cohn et al., 1999; Adisasmito-Smith, 1998, 1999a, 1999b, 2003; Podesva and Adisasmito-Smith, 1999). Further acoustic studies on these individual languages are essential to contact language studies in the area, which, in turn, would enrich our knowledge on the ways in which linguistic variables in different languages in contact adjust to each other, so to speak, and the ways in which this adjustment is acoustically manifested.

6.5 Conclusion

To conclude, this study was an attempt to systematically investigate the influence of one sound system on another in a language contact situation. Based on impressionistic observations, several variables were chosen. Systematic phonological patterns and acoustic realizations were studied to make the appropriate comparisons. The results in this study strongly supported the hypotheses. We hope that this will lead to other systematic studies of sound systems of languages in contact. Ultimately, we hope to contribute to a better understanding of what an "accent" is.

APPENDIX A: INTERVIEW QUESTIONS

In this section, I present the questions (listed in § A.1) that all recorded speakers were asked, and the summary of the interview, presented in § A.2.

A.1 List of interview questions

1. Name: ________________________________, sex: M ___ F ____
2. Year of birth: ______
3. Place of birth: ________________________
4. Other places that you have lived in, for how long: _____________
5. Occupation/s: ________________
6. When do you learn Indonesian: _________________
7. Which language (Javanese or Indonesian) do you use when you speak with (a) your parents ____________ (b) your siblings ___________ (c) your other relatives __________ (d) your friends in the classroom __________ outside the classroom _________ (e) your teachers, supervisors, elders _______ (f) others __________
8. What kind of events determines that you choose to speak Javanese or Indonesian? __________________________
9. Between Javanese and Indonesian, which one do you prefer and why? ________________________________
10. Are you married? _____ Do you have children? _____ Where is your spouse from? __________ What language do you speak with your spouse? __________ with your children? __________
11. Notes/Comments: __________________________________

Note that for the monolingual Indonesian speakers, questions 8 and 9 were skipped.[11] In number 11, I noted information such as whether the speaker was nervous while being recorded, or whether a speaker used a different 'style' of Javanese during recording vs. during interview, etc. Comments regarding the speaker's attitude and impressions about the language/s they speak are also entered in number 11.

Note also that some of the questions for the interview may be considered to be too personal in the US. However, they are all appropriate general questions in Indonesia. In fact, one needs to know this information to speak appropriately to others.

A.2 List of speakers and summary of interviews

I summarize the results of the interviews for each speaker recorded in the following. First, I present the monolingual Indonesian speakers interviewed in Jakarta in § A.2.1.a and those in the US in § A.2.1.b, then the bilingual Central Javanese/Indonesian speakers interviewed in Solo in § A.2.2.a and those in the US in § A.2.2.b, followed by the bilingual Eastern Javanese/Indonesian speakers, in § A.2.3. The speakers are represented by the abbreviation that indicates their native language background (IM = monolingual Indonesian speakers, CJ = Central Javanese speakers, EJ = Eastern Javanese speakers), and their gender: female (f) or male (m). Female speakers are listed first, followed by male

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[11] The monolingual speakers could have been asked the questions 8 and 9, with Javanese substituted for Jakarta Malay or *Bahasa Jakarta*. At the time of the interview, I assumed that Jakarta Malay and 'Standard' Indonesian would not be different with respect to vowel alternation, stop voicing, and medial NC syllabification.

speakers. Abbreviations that are printed in bold indicate those speakers whose speech is analyzed in the present study.

A.2.1.a Monolingual Indonesian speakers interviewed in Jakarta

1. IM_f1
She was born, grew up, and at the time the recording was made, resided in Jakarta. She was 25 years old, never lived elsewhere and worked in a private company. Her parents are from Central Java, but they speak Indonesian to communicate with their children. The day she was recorded, she had a cold and sore throat.

2. IM_f2
She was born, grew up, and lived in Jakarta. She was a 32-year-old government employee, and she has never lived outside Jakarta. Her parents speak Javanese to each other, and a mixture of Indonesian and Javanese to their children. Retno speaks only Indonesian, even though she understands Javanese about half of the time.

3. IM_f3
She was born, grew up, and lived in Jakarta at the time of recording. She was a 33-year-old pediatrician. She moved to West Sumatra for 3 years and to Medan, North Sumatra, for 1.5 years, after she finished her medical school training. Indonesian is her main language of communication with her husband, children, friends and others. Both her parents are from Padang, and they speak both Indonesian (or perhaps Padang Malay) and English with their children.

4. IM_f4

She was born in Jakarta, and moved to Bandung when she was 3 years old. When she was 16 years old, she moved to Pematang Siantar, Sumatra, and lived there for 3 years. She moved back to Jakarta, to go to college and has lived there ever since (i.e. for 6 years). At the time of recording, she was 25 years old and worked in a private company. She can speak only Indonesian. Her parents are from Padang and speak Indonesian (or Padang Malay) with each other and to their children.

5. IM_f5

She was born, grew up, and lived in Jakarta at the time of recording. She was 26 years old, an employee of a private company, and never moved out of town. She speaks only Indonesian, though she understands Bima (a language spoken in Bima island, West Nusa Tenggara). Her parents are from Bima island, and they speak Bima to each other. They speak Bima to the children, but Widi claimed to always respond to them in Indonesian. Her brother speaks Bima with their parents, but speaks Indonesian with her.

6. **IM_m1**

He was born, grew up and lived in Jakarta at the time of recording. He lived in the US for 5 years to obtain his PhD degree. He was 33 years old and worked as a researcher in a government office. He speaks only Indonesian (and English). His parents are from Bali and Bandung, and they speak Indonesian to each other and to their children.

7. **IM_m2**

He was born, grew up, and lived in Jakarta at the time of recording. He was 23 years old, never lived elsewhere, and an employee of a university. He speaks only Indonesian.

8. **IM_m3**

He was born, grew up and lived in Jakarta at the time of recording. He is 36 years old, never lived elsewhere, and an employee of a university. He speaks only Indonesian, and understands Javanese a little bit. His parents are Central Javanese, but they speak to him in Indonesian.

9. IM_m4

He was born, grew up, and at the time of recording, lived in Jakarta. He lived in the US for 2 years to get his master's degree. He was 33 years old and worked as a researcher in a government office. He speaks only Indonesian (and English). His parents are from Central Java, but they communicate with him in Indonesian. He understands no Javanese. He was very soft spoken. When his speech was digitized at the Cornell Phonetics Lab, it was hardly audible. Amplifying the volume during digitization caused the background noise of the room air conditioner to be as loud as his voice.

10. IM_m5

He was born, grew up and lived in Jakarta at the time of recording. He is 21 years old and never lived elsewhere. He was a third year university student. He can speak only Indonesian. He spoke very fast and made many mistakes during recording. When I asked him if he could slow down his speech, he claimed to not be able to. Looking at the spectrogram of his speech, many of his (non-schwa) vowels are considerably shorter compared to those of the other speakers.

11. IM_m6
He was born, grew up, and lived in Jakarta at the time of recording. He lived in the US for 1.5 years to get his master's degree. He was 35 years old and was a lecturer at a university. At home, he speaks the Hakka dialect of Chinese and Indonesian. He learned formal Indonesian when he entered elementary school. He was nervous during recording and the speed of his speech fluctuated significantly.

A.2.1.b Monolingual Indonesian speakers interviewed in the US

1. **IM_f6**
She was born, grew up, and lived in Jakarta, prior to coming to the US to get her doctoral degree. She has been in the US for five years. She was 35 years old. While in the US, she speaks Indonesian with other Indonesians in the area, and English with non-Indonesians.

2. **IM_f7**
She was born, grew up, and lived in Jakarta, prior to coming to the US. She has been in the US for one and a half years, accompanying her husband. She was 29 years. She speaks Indonesian with her family and other Indonesians in the area. She understands and speaks a little English.

3. **IM_m7**
He was born, grew up, and lived in Jakarta, prior to coming to the US to get his master's degree. He has been in the US for one and a half years.

He was 30 years old. He speaks Indonesian with his wife and child, and with other Indonesians in the area. He speaks English with non-Indonesians. His parents are from Central Java, but they speak Indonesian to him. He understands no Javanese.

A.2.2.a Bilingual Central Javanese/Indonesian speakers interviewed in Solo

1. CJ_f1
She was born, grew up and has lived all her life in Solo. She was 44 years old and a radio broadcaster. She speaks Javanese with her parents and siblings. She also spoke Javanese (of the high register) with her teachers when she was still at school. At work, she uses Javanese most of the time with her friends and officemates (during and off work), even though she sometimes switches to Indonesian. She communicates in Indonesian with her supervisors. Either Indonesian or Javanese is used to communicate with merchants in stores and markets. She started learning Indonesian when she entered elementary school. She prefers Javanese to Indonesian. She demonstrated what she claimed as the difference between her informal and her 'broadcasting' Indonesian. During the recording of the Indonesian data, she used the 'broadcasting' Indonesian. The speed of her speech during recording fluctuated significantly.

2. CJ_f2
She was born, grew up, and was living in Solo at the time of the recording. She was a 39-year-old housewife. She communicates in Javanese with her parents, siblings, husband, children, and friends. Sometimes she would switch to Indonesian with her classmates in school.

With her school teachers, she used Indonesian at school and would use Javanese outside the school grounds. When she goes to the stores and markets, she would use both Indonesian and Javanese, depending on whether the merchant can speak Javanese. She learned Indonesian in elementary school. She prefers Javanese to communicate with others.

3. CJ_f3

She was born, grew up, and was living in Solo at the time of the recording. She was 22 years old and a fifth year university student majoring in Javanese literature. She uses the high register in Javanese to speak with her parents and her older brother-in-law, the low register with her younger siblings, and in Indonesian with her older sister/brother. She speaks Indonesian with her friends in class, and with her teachers and professors. She speaks Javanese with her friends outside class, when she goes to the markets or stores (though she sometimes switches to Indonesian). She learned Indonesian when she was in the elementary school. She prefers using Indonesian, because it has greater vocabulary to discuss a wide range of topics.

4. CJ_f4

She was born, grew up, and was living in Solo at the time of the recording. She was a 29-year-old employee of a radio station. She speaks Javanese with her parents, siblings, husband, friends, and office mates, even though occasionally she switches to Indonesian with her friends and office mates. She spoke Indonesian with her school teachers. In formal occasions, she uses Indonesian, but in informal occasions, she may use

Indonesian or Javanese. She learned Indonesian in elementary school. She prefers to speak Indonesian.

5. CJ_f5

She was born, grew up, and lived in Solo. She was a 22-year-old fourth year university student, majoring in Javanese literature. She speaks Javanese with her parents, her siblings, her school and college friends, her teachers and professors outside class, and with others during any informal occasions. She speaks Indonesian in classroom situations, with her teachers and professors (in most cases), and occasionally with merchants in the stores. In formal situations she switches back and forth between Indonesian and Javanese topics. She learned Indonesian when she entered elementary school. She prefers to communicate in Indonesian, since it makes it easier for her to discuss a wide range of topics. Throughout the recording, there were burst/popping noises accompanying her speech that show up in the spectrogram. It is unclear what the source of this noise is.

6. CJ_f6

She was born in Solo, moved to Klaten (about 45 km west of Solo) when she was four years old, and moved back to Solo when she was 13 years old. She was 23 years old and was a fifth year university student, majoring in Javanese literature. She speaks Javanese with her parents, her siblings, her classmates when they are outside of school, with her teachers in informal occasions, with merchants in the markets, and in any informal gatherings. She speaks Indonesian in classroom situations, with her teachers and professors, in meetings, and sometimes when she goes to the stores. She learned Indonesian when she entered kindergarten. She prefers to communicate in Indonesian.

7. **CJ_m1**

He was born, grew up, and was living in Solo at the time of the recording. He was 35 years old and worked for a radio station. He communicates in Javanese for almost all occasions: with his parents and siblings, friends and office mates, and any informal gathering. He uses (or used) Indonesian with his teachers at school, when he speaks with his supervisors, during formal occasions like meetings, and when he speaks to a non-Javanese person. He learned Indonesian when he entered elementary school. He claimed to have no preference for speaking Javanese or Indonesian.

8. **CJ_m2**

He was born, grew up and was living in Solo at the time of the recording. He lived in Ambon for one year and in Jakarta for two years. He was a 33-year-old radio broadcaster and the manager of the radio station. The language of communication he uses with his parents and siblings is Javanese, but he communicates in Indonesian in addition to in Javanese with his wife. In informal occasions he mostly uses Javanese; in all formal contexts, he switches to Indonesian. He communicated in the high register of Javanese with his teachers, and in Indonesian with his supervisors (e.g. the owner of the radio station). When he goes to the stores or markets, he uses Indonesian or Javanese, depending on which language the merchant can speak. He learned Indonesian when he entered elementary school. While he chooses Indonesian or Javanese to communicate on need-based and on context-based, he prefers to use Indonesian since in his view, it has greater vocabulary to discuss matters like politics, technology, etc.

9. **CJ_m3**

He was born, grew up and was living in Solo at the time of recording. He was a 44-year-old employee of a radio station. He speaks Javanese with his family and relatives, as well as with his friends. In formal contexts he switches to Indonesian, including conversing with his supervisors. With others, he would use either Javanese or Indonesian depending on which language the other person can speak. He learned Indonesian when he entered elementary school. He has no preference over using Javanese or Indonesian.

10. CJ_m4

This speaker was born, grew up, and was living in Solo at the time of the recording. He was a 35-year-old radio broadcaster. He grew up speaking Javanese with his parents, his siblings, and his friends. Sometimes he switches to Indonesian when he talks to his friends. He also switches back and forth between Javanese and Indonesian with his officemates, even though off work, he tends to use Javanese with them. To communicate with his teachers, he used Indonesian when he was in school, though he switched to the high register of Javanese outside of school. He uses either Indonesian or Javanese when he goes to the stores and markets, depending on whether the merchants can speak Javanese and/or Indonesian. He chooses Indonesian for formal occasions, and

Javanese for informal ones; he prefers Javanese nevertheless. He started learning Indonesian in elementary school.

11. CJ_m5
This speaker was born, grew up, and was living in Solo at the time of the recording. He was 24 years old and a fifth year university student majoring in Javanese linguistics; he was writing his bachelor's thesis on the structure of embedded clauses in Javanese. He speaks Javanese with his parents and siblings, with his friends when they are outside of school, with his teachers and professors (in the high register), with merchants in the stores or markets (as long as they understand Javanese), and in any informal occasions. Even though he prefers to use Javanese, he communicates in Indonesian when he discusses school matters with his friends (in high school and in college), when he has to consult with his teachers and professors, and in academic meetings. He learned Indonesian in elementary school.

A.2.2.b Bilingual Central Javanese/Indonesian speakers interviewed in the US

1. **CJ_f7**
She was born, and grew up in Solo. She has been in the US for 10 years. She speaks Javanese with her husband, and Indonesian and English with her children. In addition to working as an employee in an office, she also regularly performs as a singer in *wayang* shadow plays at the Indonesian representative offices and at different universities.

2. **CJ_m6**

He was born, and grew up in Solo. He has been in the US for 15 years to teach Javanese music and *wayang* shadow plays. In addition, he regularly performs as a puppeteer ("*dalang*") in these shadow plays, which involves presenting dialogues of characters and singing. He speaks Javanese with his wife.

3. **CJ_m7**

He was born in Mojokerto, East Java, and moved to Solo when he was a teenager. He has been in the US for 12 years to teach Javanese music and *wayang* shadow plays. He regularly performs as a puppeteer in these shadow plays. He speaks Javanese with his wife and English with his children.

A.2.3 Bilingual Eastern Javanese/Indonesian speakers

1. EJ_f1

She was born, grew up and lived in Malang. She was a 24-year-old elementary school teacher. She speaks Javanese at home, with her parents and siblings. With her friends at school she uses both Indonesian and Javanese to communicate, but exclusively Indonesian in class. She conversed with her teachers mostly in Indonesian, but sometimes she would use the high register of Javanese. She learned Indonesian when she entered elementary school. She prefers to speak in the low register of Javanese (*ngoko*). Throughout the duration of the recording, there were burst/popping noises accompanying her speech, similar to the case with the bilingual speaker from Central Java, Tyas. These noises were visible in the spectrogram.

2. EJ_f2

She was born, grew up, and lived in Malang. She was 33 years old and a university employee. She speaks Javanese with her parents and siblings, as well as in any informal occasions. When she was still at school, she used mostly Javanese with her friends, and only sometimes used Indonesian. The reverse was the case when she communicated with her teachers. At work, she mostly speaks Indonesian with her officemates and her supervisors, but she switches to Javanese (the high register, with her supervisors) outside office hours. Both Javanese (the high register) and Indonesian are used when she attends a meeting or goes to a party. She learned Indonesian in kindergarten. For her, the choice between Indonesian or Javanese depends on the occasion, not on preference.

3. EJ_f3

This speaker was born in Malang, moved to Kalipare (east of Malang) for nine years, and returned to Malang. She was a 20-year-old third year college student. The language of communication at home is Javanese: the high register with her parents, and the low register with her siblings. With her friends, she speaks Javanese (the low register) outside school, and speaks Indonesian while in class. To communicate with her teachers and other older people, she speaks both Indonesian and the high register of Javanese. In all formal occasions, she speaks Indonesian, while in informal gatherings she uses Javanese. She learned Indonesian in elementary school. Her choice of Indonesian or Javanese depends on how well she knows the person; she would speak Javanese with someone she knows, otherwise she would speak Indonesian. At the time of the recording, she had a cold and sore throat.

4. EJ_f4

She was born and grew up in Malang. She went to college in Bogor (south of Jakarta) for five years and worked in Cirebon (east of Jakarta) for three years, before moving back to Malang. She was 32 years old. She speaks Indonesian and Javanese with her parents, her brother, and her husband. While she was still at school, she used Indonesian with her friends to discuss school matters, but she switched to Javanese otherwise. She spoke mostly Indonesian when she was in the college and in the office. She prefers Javanese because for her, it reflects closeness and it is not as impersonal as Indonesian. During unrecorded conversations (she and her husband were my hosts during my stay in Malang), she clearly showed the Eastern Javanese pattern with respect to vowel harmony, whether the conversation was in Indonesian or in Javanese. However, during recording the vowel harmony never showed up.

5. EJ_f5

This speaker was born, grew up, and lived in Malang. She was 28 years old, a housewife with two children. She speaks Javanese with her parents, siblings, her husband, and her friends. However, she speaks Indonesian with her four-year-old son; her reasoning was that Indonesian has become more and more the language of communication and it would be better for her son to learn the language that is actually used. With her teachers and in meetings, she speaks Indonesian. She learned Indonesian when she entered kindergarten. She has no preference between Indonesian and Javanese.

6. EJ_f6

This speaker was born, grew up, and lived in Malang. She was a 29-year-old housewife. She speaks Javanese almost exclusively with her parents, and her husband, a Madurese descent who was born, grew up, and lived in Malang, and who speaks Indonesian and Javanese, but no Madurese. She also speaks Javanese with her friends. She speaks Indonesian with her teachers, and during meetings (e.g. *arisan*) with the women whose husband worked in the same company as hers. She prefers Javanese to Indonesian, because she feels that she sounds '*medhok*' (i.e. 'breathy') when she speaks Indonesian. During the unrecorded conversation (before and after recording), she showed the Eastern Javanese pattern with respect to vowel harmony. However, during recording, the vowel harmony disappeared.

7. **EJ_m1**

He was born in Bondowoso (east of Malang), and moved to Malang when he was three years old. At the time of recording, he was 27 years old and just graduated from college. He speaks Javanese with his parents, siblings, and friends, and in almost any informal occasions. Indonesian is his choice when he communicates with others, on formal occasions such as parties and meetings, and with his teachers. He started learning Indonesian when he entered elementary school. For him, the choice between using Indonesian or Javanese is not determined by personal preference, but rather by occasion.

8. **EJ_m2**

He was born and grew up in Malang, and has been there all his life. He was a 19-year-old first year college student. Javanese is the language of communication with his parents, siblings and friends (at school and outside school). He speaks Indonesian with his teachers, and speaks either Indonesian or Javanese in stores and markets. His choice of Indonesian and Javanese depends on who he talks to. He learned Indonesian in elementary school. He had preferred Javanese, but has developed preference for Indonesian, because in his view it is the official language and more widely spoken.

9. **EJ_m3**

He was born and grew up in Malang. He went to college in Surabaya, and worked in Probolinggo (on the north coast, east of Malang) for two and a half years and in Paiton (northwest of Surabaya) for four years. At the time of the recording, he lived in Malang, but commuted every day to Surabaya to work. He was 33 years old. He speaks Javanese with his parents, siblings, his friends, and in informal occasions. He speaks Indonesian and Javanese with his wife. He speaks Indonesian with his teachers, when he is at work, and in all other formal occasions. He started learning Indonesian in kindergarten. Of the two languages, he prefers Javanese.

10. EJ_m4

He was born in Malang, and has been there all his life. He was a 20-year-old second year college student. He mostly uses Javanese at home (with his parents and siblings), in or out of school (with his friends), or at the stores and markets. He uses Indonesian only occasionally, such as with his teachers; he would use Javanese too with them, if the occasion is informal. He prefers Javanese to communicate. He started learning Indonesian when he entered kindergarten.

11. EJ_m5

This speaker was born in Malang and has been there all his life. He was 19 years old and was in his first year of college. He speaks Javanese at home, with his parents and siblings. Outside of home, he switches back and forth between Indonesian and Javanese quite regularly, with his friends and others. With his teachers and in all other formal occasions, he speaks Indonesian. He started learning Indonesian when he entered kindergarten. He prefers Indonesian for communication, since in his view Javanese has too many rules (i.e. certain words can only be used for certain occasions with certain people).

12. EJ_m6

He was born, grew up, and lived in Malang. He was 24 years old, and worked as a security guard for a neighborhood. He speaks Javanese with his parents, his siblings, his wife, and his friends, as well as in all informal occasions. He speaks Indonesian with his teachers, and during formal occasions. He learned Indonesian in elementary school. As a mode of communication, he prefers Javanese.

13. EJ_m7

He was born and grew up in Malang. He was an 18-year-old first year college student. He speaks Indonesian with his parents (his father is from

Pontianak, West Kalimantan, and his mother is from Malang) and with his younger sibling, but Javanese with his older sibling. He uses both Indonesian and Javanese to communicate with his friends, whether inside or outside of classroom. Indonesian is his preferred mode of communication for almost all occasions. He learned Javanese, as a second language, from his friends.

APPENDIX B: MEASUREMENTS OF FUNDAMENTAL FREQUENCY AND AMPLITUDE DIFFERENCE FOR VOWELS IN JAVANESE AND INDONESIAN

In this appendix, I present the acoustic measurements for vowel alternation, namely the fundamental frequencies (F0) and amplitude differences of Indonesian and Javanese vowels, in the penultimate and final syllables. As can be seen in the vowel alternation study in Chapter 3, the acoustic measurements of the F0 and amplitude differences of Javanese vowels in the final syllable do not really yield significant results. This is also the case with vowels in Indonesian. However, since so little is known about them, the results are discussed here.

The order of presentation in this section is as follows. In § B.1, I present the results of vowel F0 and amplitude differences of penultimate vowels in Javanese. In § B.2, I present the results of vowel F0 and amplitude differences of final vowels in Indonesian, and in § B.3, I present the results for the penultimate vowels in Indonesian.

B.1 F0 and amplitude difference measurements of penultimate vowels in Javanese

The order of presentation in this section is as follows. In § B.1.1, I present the measurement results of F0 for the penultimate vowels in Javanese, and in § B.1.2, I present the results of amplitude difference for these vowels. In § B.1.3, I briefly summarize the results.

B.1.1 Vowel fundamental frequency

As discussed previously, the general pattern with respect to F0 is that high vowels tend to have higher F0 as compared to low vowels (see, e.g., House and Fairbanks, 1953). Comparing Javanese vowels in the penult, we would expect to see this general pattern. In addition, we may see that lax vowels, resulting from vowel harmony, have lower F0 as compared to their tense counterpart, and that vowel pairs with impressionistic similarity would have similar F0.

The order of analysis here is as follows: (a) different vowels preceding final syllables of the same structure, (b) the same vowel preceding open vs. closed final syllables, and (c) vowels that are impressionistically similar. The F0 measurements of Javanese vowels in the penult, as produced by the Central Javanese speakers, are shown in Figure B.1.

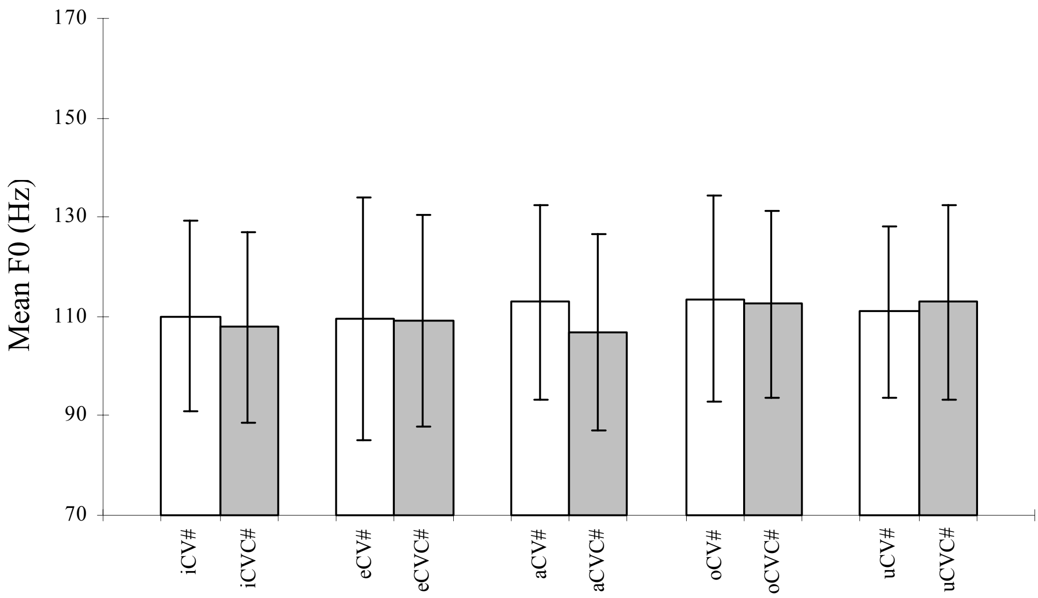

Figure B.1: Mean overall F0 values (in Hz) of Javanese penultimate vowels preceding open vs. closed final syllables for the Central Javanese speakers

The differences in the mean F0 values for vowels of different heights are quite small. In the CVCV case, the mean values for /a/ and /o/ are similar (113 Hz). The values for /i/ and /e/ (both at 110 Hz) are slightly greater than the value for /u/ (111 Hz). In the CVCVC case, /a/ has the lowest mean value (107 Hz). The vowels /u/ and /o/ have comparable mean values (113 Hz), which are greater than the mean values for /i/ (108 Hz) and for /e/ (109 Hz). Statistically, the differences in the mean F0 values for these vowels are not significant.

Comparing the same vowel in the penultimate position in CVCVC# vs. CVCV# cases, the mean value differences are quite small, ranging between 1-2 Hz, for /i/, /e/, /o/, and /u/. For the low vowel /a/ (realized as [a] in CVCVC# case and as [ɔ] in CVCV# case), the mean value difference is 6 Hz. Statistically, these differences are not significant. The vowels /i/ and /u/ in the penultimate position in CVCVC# vs. CVCV# cases are impressionistically similar for the Central Javanese speakers. Another vowel pair that is impressionistically similar is the pair of /a/ in CVCV# and /o/ in CVCVC#. The mean F0 values of these two vowels are comparable.

To summarize briefly, the F0 results for the penultimate vowels for the monolingual speakers seems to indicate that the inherent fundamental frequency of vowels with different heights is not acoustically realized for these particular set of words analyzed here. With respect to vowel pairs that are impressionistically similar, one would be tempted to say that they also have similar F0. However, vowels that are acoustically **not** similar, e.g. the penultimate /e/ in CVCV# vs. CVCVC# cases ([e] vs. [ɛ]), also exhibit similar F0. Thus, it seems to be the case that F0 does not play a role in the impressionistic similarity of the penultimate vowels, in the Javanese of the speakers from the Central Java.

Next, I discuss the F0 of the penultimate vowels for the Eastern Javanese speakers. The mean values for these vowels are shown in Figure B.2.

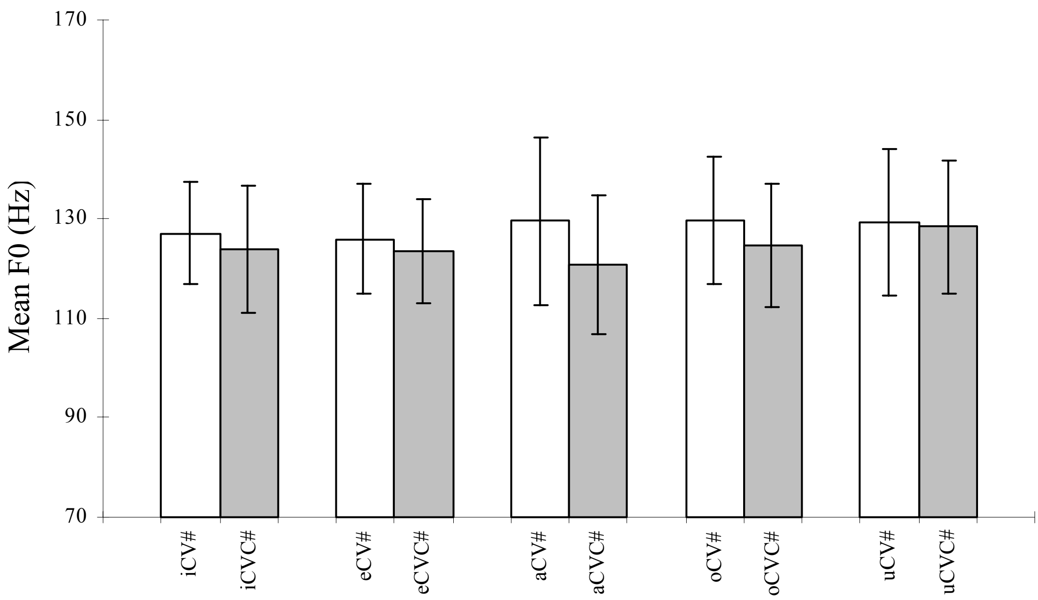

Figure B.2: Mean overall F0 values (in Hz) of penultimate Javanese vowels preceding open vs. closed final syllables for the Eastern Javanese speakers

In the CVCV case, the vowels in the penult have similar mean F0 values, ranging from 126-130 Hz, with the mean values for the vowels /i/, /o/, and /a/ being higher than those for the vowels /e/ and /u/. In the CVCVC case, the mean values for /i/, /e/, and /o/ are similar (124 Hz). The mean value for /a/ is the lowest, at 121 Hz; for /u/, it is the greatest, at

128 Hz. The differences of the mean F0 values do not reach statistic significance.

Comparing the penultimate vowels in CVCV# vs. CVCVC# word forms, those in CVCV# tend to have greater mean F0 value than those in CVCVC#. The differences of the mean F0 values range from 1 Hz for /u/ to 9 Hz for /a/. Statistically, these differences are not significant. One may argue that this consistent pattern of F0 differences is due to the structure of the final syllable and/or due to vowel quality (i.e. that the lower vowel alternate has lower F0). Note that the structure of the final syllable determines vowel alternation.

With respect to the vowels that are impressionistically similar, /i/ in CiCiC# is 2 Hz lower than /e/ in CeCe#, /u/ in CuCuC# is 1 Hz lower than /o/ in CoCo#; /a/ in CaCa# is 5 Hz greater than /o/ in CoCoC#. The results here seem to suggest that F0 does not contribute to the perceived similarity of these vowel pairs.

The overall results of F0 pattern for vowels in the penult as produced by the Eastern Javanese speakers show that the correlation between vowel height and vowel F0 does not consistently apply here. Comparing the F0 measurement results for the Central and the Eastern Javanese speakers, Javanese vowels in the penult for the former group show less of a systematic pattern, when compared to the latter. In the next section, I analyze the amplitude of Javanese vowels in the penult for these two speaker groups.

B.1.2 Vowel amplitude

High vowels have been found to have lower relative amplitude as compared to low vowels, with as much as 5 dB difference (Ladefoged, 2001). We have found this to be the case for the Javanese high and mid vowels in the final syllables, for the Eastern Javanese speakers (see Chapter 3, § 3.3.4). In addition, we also found that tense vowels tend to have lower relative amplitude as compared to their lax counterpart. The analysis of vowel amplitude here is carried out by examining the difference of the relative amplitude of the anchor vowel /a/ and a target vowel in the penultimate syllable, as is the case in Chapter 3. Higher vowels are predicted to have higher **amplitude difference** as compared to lower vowels. This prediction translates to higher vowels having lower **relative amplitude** and lower vowels higher relative amplitude.

The order of presentation is the following: (a) comparison of vowels in the penult followed by final syllables of the same structure, (b) comparison of the same vowel in the penult followed by final syllables of different structures, and (c) comparison of vowels that are impressionistically similar. First, I present the amplitude measurements of Javanese vowels for the Central Javanese speakers. The results are shown in Figure B.3.

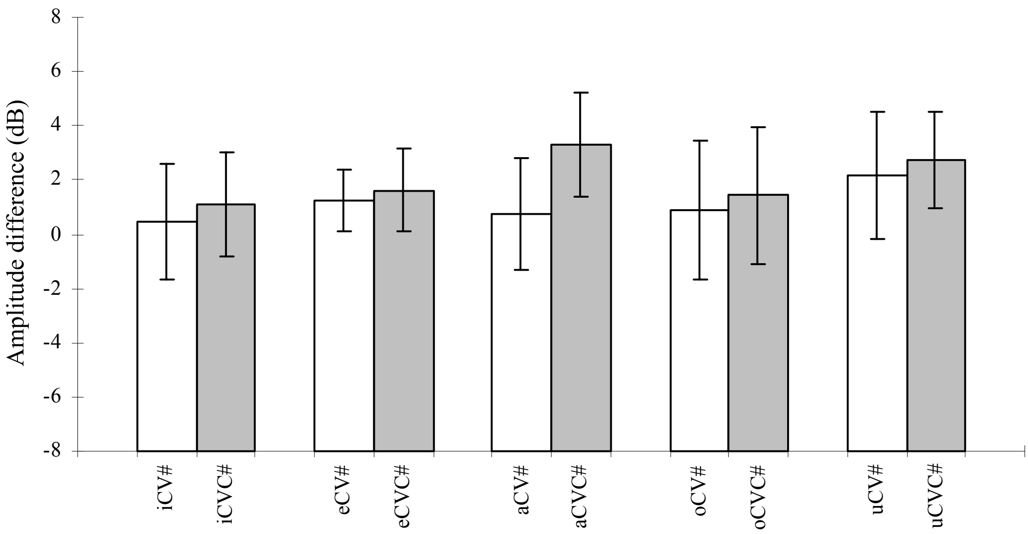

Figure B.3: Differences of the mean amplitude of Javanese /a/ of the frame sentence vs. the mean amplitude (in dB) of penultimate vowels preceding open and closed final syllables, for the Central Javanese speakers

In the case of the penultimate vowels preceding open final syllables, /a/ (realized as [ɔ]) shows to have lower amplitude difference mean value when compared to the mid vowels (though only slightly) and /u/, and it has similar amplitude difference as /i/. The mid vowels have lower mean values as compared to /u/, and slightly greater values as compared to /i/. These results indicate that lower vowels have greater relative amplitude than higher vowels, except /i/. Preceding closed final syllables, /a/ shows to have the greatest amplitude difference when compared to the other vowels. The amplitude difference for /e/ is slightly greater than it is for /i/. This is contrary to the expected pattern. The amplitude difference for /o/ is lower than it is for /u/. Statistically, the mean value differences are significant ($p < .05$) for CiC# vs. CaC# and

CeC# vs. CaC#; they are marginally significant for CiC# vs. CuC# ($p = .04$) and CaC# vs. CoC# ($p = .05$). Overall, the results here indicate that only the high and mid back vowels show the predicted correlation between vowel height and vowel amplitude difference, and thus relative amplitude of vowels.

Comparing the same vowel in the penult preceding open vs. closed final syllables, the mean value of amplitude difference for a penultimate vowel preceding an open final syllable is smaller than for a penultimate vowel preceding a closed final syllable. This is the case for all vowels, except for /u/, in which case the mean value is greater preceding an open final syllable than preceding a closed final syllable. The mean value differences are statistically significant ($p < .05$) only for /a/. This result suggests that, on the one hand, a vowel can have greater or lower amplitude difference in different environments, and, on the other hand, higher and lower vowels may have similar amplitude difference. Thus, the result here does not show the expected pattern.

We have seen in Chapter 3, that for the Central Javanese speakers, high vowels in the penult exhibit similar formant structure (thus similar quality), whether the following final syllable is open or closed (see Figure 3.12). In addition, /a/ in the penult preceding an open final syllable and /o/ in the penult preceding a closed final syllable have similar formant structures. With respect to the amplitude difference of these vowels, the mean value difference for /i/ is very small, the difference for /u/ is about 2 dB, and the mean value difference for the aCV# case vs. the oCVC# case is negligible. This indicates that in some cases, the same phonological vowels or vowels of similar acoustic quality, in the penultimate position, may have different amplitude difference (when compared to the anchor vowel /a/), thus relative amplitude, whether the following final syllable is CV or CVC.

Next, I turn to the case of Javanese vowels in the penult for the Eastern Javanese speakers. The results are presented in Figure B.4.

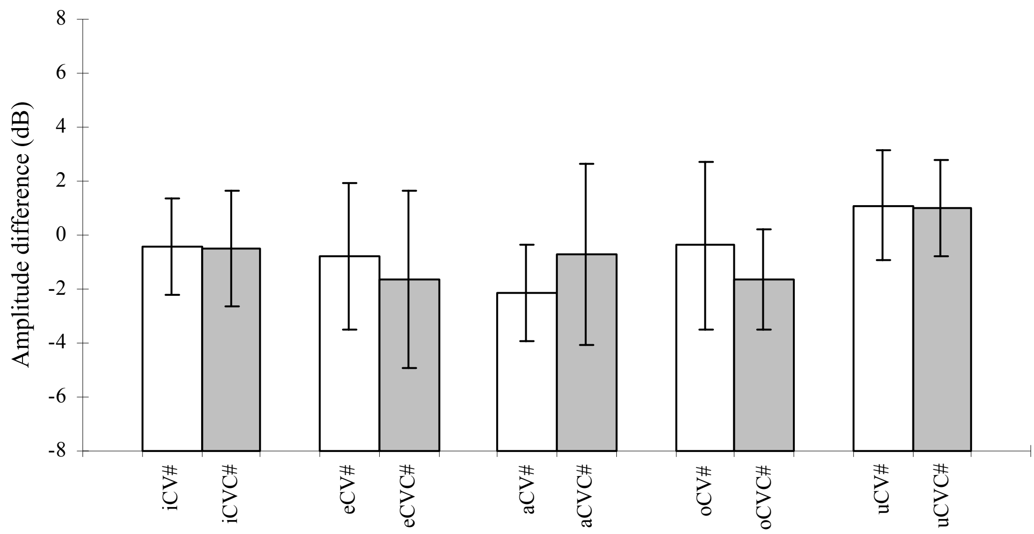

Figure B.4: Differences of the mean amplitude of Javanese /a/ of the frame sentence vs. the mean amplitude (in dB) of penultimate vowels preceding open and closed final syllables, for the Eastern Javanese speakers

In the case of penultimate vowels preceding an open final syllable, the amplitude difference mean value for /a/ is lower than for the mid vowels /e/ and /o/, which in turn have lower amplitude difference mean values than the high vowels /i/ and /u/. The mean value difference between /i/ and /e/ is quite small. In the case of vowels preceding a closed final syllable, the amplitude difference mean value for /a/ is greater than for the mid vowels. This implies that the relative amplitude of [a] is lower, rather than greater as we would expect, as compared to the relative amplitude of [ɛ] and [ɔ]. The mean value of amplitude difference for /a/ is similar to /i/, but it is lower than for /u/. It is lower for the mid vowels than for the high vowels. The mean value differences are statistically significant ($p < .05$) for Ci# vs. Ca#, Ca# vs. Cu# CeC# vs. CuC#, and CoC# vs. CuC#; they are marginally significant for Ca# vs. Co# ($p = .06$) and CiC# vs. CuC# ($p = .05$).

Comparing the same vowels in the penult preceding open vs. closed final syllables, the amplitude difference mean value is similar for /i/ and /u/. For /e/ and for /o/, it is greater preceding open final syllables than preceding closed ones. For /a/, it is lower preceding open syllables than preceding closed syllables. These mean value differences do not reach statistic significance. These results indicate that vowels that are acoustically lower (e.g., and aCVC# vs. aCV#) do not necessarily have lower amplitude differences as predicted. For example, in the case of iCVC# vs. iCV#, the mean values are similar, and in the case of aCVC# vs. aCV#, they are greater for aCVC#, in which /a/ is realized as the lower vowel alternate.

Recall that, impressionistically, vowels in the penult undergo harmony for the Eastern Javanese speakers. Thus, preceding closed final syllables, high and mid vowels would lower and low vowel would raise. The lowered high vowels are impressionistically similar to the non-lowered mid vowels, and the raised low vowel is impressionistically similar to the lowered mid back vowel. With respect to their amplitude difference, the mean values are similar for /i/ in iCVC# vs. /e/ in eCV# and for /o/ in oCVC# vs. /a/ in aCV#. The mean value for /u/ in uCVC# is greater than for /o/ in oCV#. As we have seen earlier in Chapter 3, Figure 3.12, /u/ in uCVC#, though lower in the acoustic space as compared to /u/ in CV#, is higher and more centralized than /o/ in oCV#. One could argue this to be the reason for the difference in the mean values of amplitude difference for /u/ in uCVC# and /o/ in oCV#.

To briefly summarize, the amplitude difference of vowels in the penultimate syllable for the Eastern Javanese speakers is, in some cases, in accord with the predicted pattern (i.e. in the CVCV# cases), but is not in the other cases. Comparing the Eastern and the Central Javanese speakers, the overall results of the amplitude difference measurement seem to be consistent, in that there are cases where vowels exhibit the predicted amplitude pattern, but there are other cases where they do not. It seems that environment (e.g. the shape of the following syllable, or the preceding and the following consonants) does not play a role in whether or not the predicted pattern is realized.

B.1.3 Summary

In Table C.1, I present the summary of the fundamental frequency and amplitude difference results for penultimate vowels in Javanese, for both the Central Javanese and the Eastern Javanese speakers. Bold prints indicate differences among the speaker groups. The results suggest no systematic correspondence with the alternation of Javanese vowels in the penultimate syllable. As pointed out in Chapter 3, the most prominent cue to the centralization of penultimate vowels as a result of the harmonizing process is vowel formant structure.

Table B.1: Summary of F0 and amplitude difference measurements of Javanese vowels in the penultimate syllables

	Central Javanese	Eastern Javanese
Fundament-al frequency	**1. Vowel height does not correspond with the expected pattern of vowel F0** 2. Vowel pairs that are impressionistically similar have similar F0, but so are vowels that are not	**1. Vowel height does not <u>always</u> correspond with the expected pattern of vowel F0** 2. Vowel pairs that are impressionistically similar have similar F0, but so are vowels that are not
Amplitude difference	Vowel height does not necessarily correspond with the predicted pattern of vowel amplitude	Vowel height does not necessarily correspond with the predicted pattern of vowel amplitude

In the next section, I present the F0 and amplitude difference measurements for the Indonesian vowels in the final syllable.

B.2 F0 and amplitude difference measurements of word-final vowels in Indonesian

The structure of this section is as follows. In § B.2.1, I present the measurements of vowel F0, and in § B.2.2, I present the measurements of vowel amplitude difference. In § B.2.3, I briefly summarize the results.

B.2.1 Vowel fundamental frequency

As discussed earlier, high vowels have been shown to have the tendency of higher F0 as compared to lower vowels. In addition, what we may find here is that lowered vowels (i.e. vowels in closed syllables) show lower F0 as compared to their non-lowered counterparts.

The analysis of vowel F0 proceeds as follows: (a) vowels in the same syllable type are compared, (b) vowels are compared in open vs. closed syllables, and (c) vowels that are impressionistically similar (i.e. CiC# vs. Ce# and CuC# vs. Co#, especially as produced by the bilingual speakers) are compared. Measurements of the mean F0 values of Indonesian vowels as produced by the monolingual speakers are shown in Figure B.5.

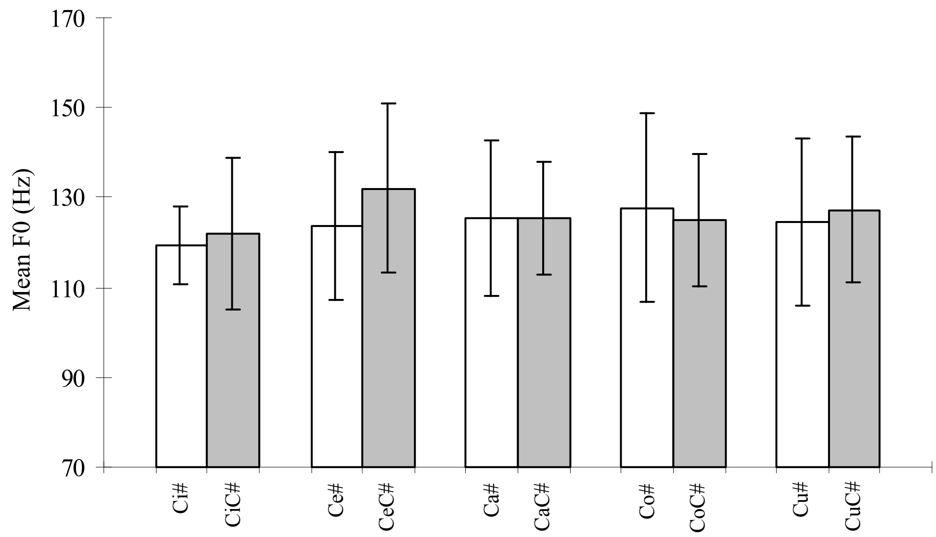

Figure B.5: Mean overall F0 values (in Hz) of Indonesian final vowels in open vs. closed syllables for the monolingual Indonesian speakers

As shown here, in the CV# cases, /o/ has the highest mean F0 value (128 Hz), the mean values for /e/, /a/, and /u/ are comparable (124-125 Hz), and /i/ has the lowest mean value (120 Hz). In the CVC# cases, /e/ has the highest mean F0 value (132 Hz) and /i/ the lowest (122 Hz), and the mean values for /o/ and /a/ are similar (125 Hz). The mean differences of these vowels do not reach statistic significance, both in the CV and in the CVC cases.

As we have seen earlier in Chapter 3, Figure 3.16, non-low vowels are lower in CVC# as compared to in CV#, in the Indonesian of the monolingual speakers. One may find the lowered vowel in CVC# to have lower F0 when compared to its counterpart in CV#. This is the case only for /o/, with the mean value difference of 3 Hz. Recall that in Indonesian, /a/ in Ca# is acoustically similar to /a/ in CaC#; their F0 mean values are shown to be similar.

This result may indicate that even though higher vowels may have the tendency to have higher F0, it is not systematically shown in the Indonesian case. This appears to be the case for vowels of different phonemic heights, as well as those of different acoustic heights (i.e. those vowels whose lowering is phonetic, rather than phonological, in nature).

I turn now to the F0 measurements of the Indonesian vowels as produced by the bilingual Central Javanese/Indonesian speakers. The results are shown in Figure B.6.

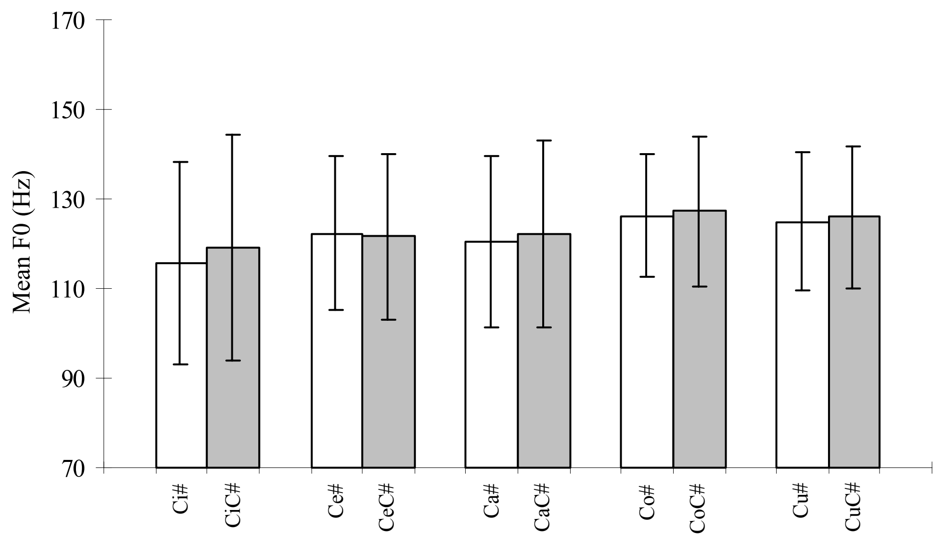

Figure B.6: Mean overall F0 values (in Hz) of Indonesian final vowels in open vs. closed syllables for the bilingual Central Javanese/Indonesian speakers

Comparing vowels in the CV cases, /o/ has the highest mean value (126 Hz), and /i/ has the lowest (116 Hz). This result is mirrored in the CVC cases with the highest and the lowest values being 127 Hz and 119 Hz. The mean value differences are small and do not reach statistic significance, both in the CV and in the CVC cases.

Comparing vowels in CV vs. CVC cases, the results show that the mean differences are quite small, ranging between 1 to 3 Hz. The result also shows that the mean F0 values tend to be slightly greater in the CVC cases than in the CV cases for these vowels, except for /e/. None of the differences here reaches statistic significance.

With respect to vowels that are impressionistically similar, we would expect that they would have similar F0 values. The mean F0 value for the high vowel /i/ in CiC# is 3 Hz lower than the mean value for the mid vowel /e/ in Ce#. For the back vowels, the mean values for /u/ in CuC# and for /o/ in Co# are similar. The difference of 3 Hz for the front vowel case is statistically not significant.

The overall result of the F0 measurements for the bilingual speakers from Central Java seems to indicate that higher vowels do not exhibit systematic pattern of higher F0 as compared to lower vowels. Recall that the acoustic measurements of vowel F0 in Javanese as produced by these speakers do not show the correlation between F0 and vowel height either.

Turning to the F0 measurements of Indonesian final vowels as produced by the bilingual speakers from East Java, I show the results in Figure B.7.

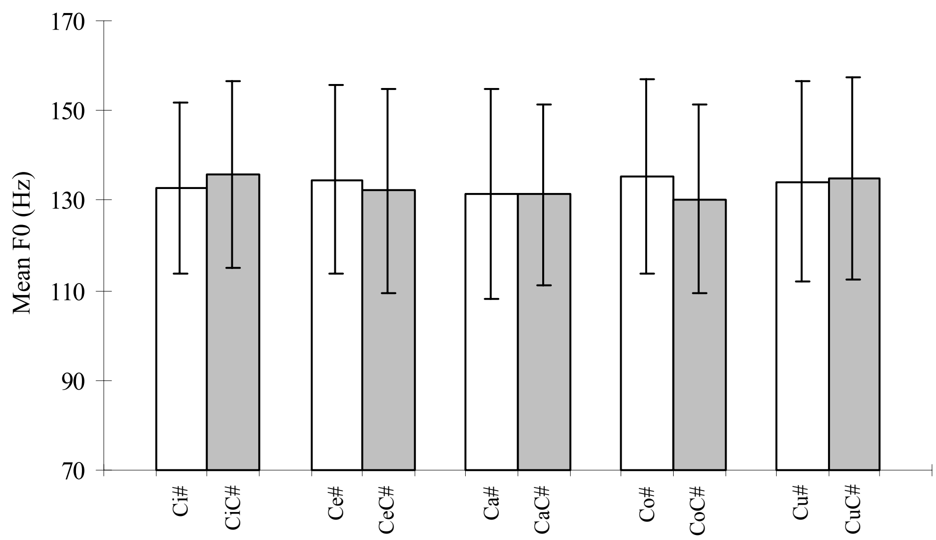

Figure B.7: Mean overall F0 values (in Hz) of Indonesian final vowels in open vs. closed syllables for the bilingual Eastern Javanese/Indonesian speakers

Comparing vowels in the CV cases, the mean F0 values for the high vowels are slightly lower than for the mid vowels. The low vowel /a/ has the lowest mean F0 value. The differences of mean values for these vowels are quite small, ranging from 1 Hz to 5 Hz. In the CVC cases, the high vowels are seen to have higher mean F0 values as compared to the lower vowels. The mean values for /a/ in CaC# and /e/ in CeC# are similar. /o/ in CoC# has the lowest mean value as compared to the other vowels. The differences of the mean values range from 1 Hz to 6 Hz. These differences are statistically not significant, both in the final CV and in the final CVC cases.

For vowels in final CV vs. CVC syllables, there does not seem to be a consistent pattern. For /i/ and /u/, the mean F0 values are slightly lower in CV# vs. CVC# syllables (1-3 Hz difference). For /e/ and /o/, they are slightly greater in CV# vs. CVC# syllables (3-5 Hz difference). For /a/, they are comparable. Statistical analysis indicates that the mean differences for vowels in final CV vs. CVC syllables are not significant.

For vowels that are impressionistically similar, the mean value for /i/ in CiC# is 1 Hz higher than for /e/ in Ce#; the mean values for /u/ in CuC# and /o/ in Co# are similar. These differences do not reach statistic significance.

To summarize briefly the overall results, vowels in Indonesian do not seem to exhibit a consistent pattern with respect to the correlation of vowel F0 and vowel height, at least in final syllable position. This is the case for all three speaker groups. It is interesting to note that for these speakers, there is also a tendency for the high vowels, especially /i/, to have the lowest F0 mean value. It is not clear why this is the case. In the next section, I turn to the analysis of vowel amplitude.

B.2.2 Vowel amplitude

As discussed earlier, high vowels tend to have lower relative amplitude as compared to lower vowels. Based on the results that we have seen so far for the Javanese vowels, this pattern is not borne out. In this section, we present the measurements for the Indonesian vowels. Recall that the results presented here are not the actual amplitude values, but rather the difference of the relative amplitude of the anchor vowel /a/ in the frame sentence (i.e. the penultimate /a/ in *dibaca*) and the relative amplitude of a target vowel. If the amplitude differences for the target vowels show the expected pattern, they would be greatest for the high vowels and lowest for /a/. This in turn implies that high vowels have the lowest relative amplitude and low vowels have the greatest.

The results of the amplitude differences of the Indonesian vowels in final syllables as produced by the monolingual speakers are presented in Figure B.8. First, I compare the amplitude differences of vowels in the same syllable type, and then I compare the amplitude differences of the same vowel in different syllable types.

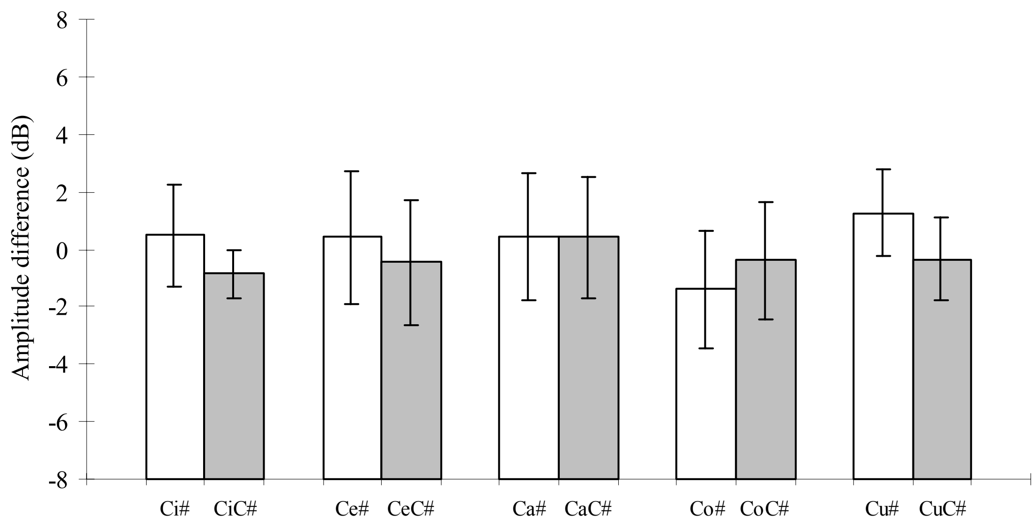

Figure B.8: Differences of the mean amplitude (in dB) of Indonesian /a/ of the frame sentence vs. the mean amplitude of final vowels in open and closed syllables for the monolingual speakers

In the open final syllables, the mean values of amplitude difference are similar for /i/, /e/, and /a/. For /o/, it is lower as compared to these three vowels, while for /u/, it is greater. In the closed final syllables, the mean values of amplitude difference are similar for /e/, /o/, and /u/. They are slightly lower for /i/ and slightly higher for /a/, as compared to /e/, /o/, and /u/. In both the open and final syllable cases, the mean value differences are significant ($p < .05$) for Ci# vs. Co# and Co# vs. Cu#; they are marginally significant for Ce# vs. Co# ($p = .05$), Ca# vs. Co# ($p = .04$), and CiC# vs. CaC# ($p = .06$).

Comparing vowels in open vs. closed final syllables, the mean values of amplitude difference are similar for /a/. They are greater in the open final syllables than in the closed ones for /i/, /e/, and /u/. For /o/, they are lower in the open than in the closed final syllables. The mean value differences for the high vowels in CV# vs. CVC# are statistically significant ($p < .05$).

Next, I present the mean values of amplitude difference for the Indonesian vowels as produced by the bilingual Central Javanese speakers. The results are presented in Figure B.9.

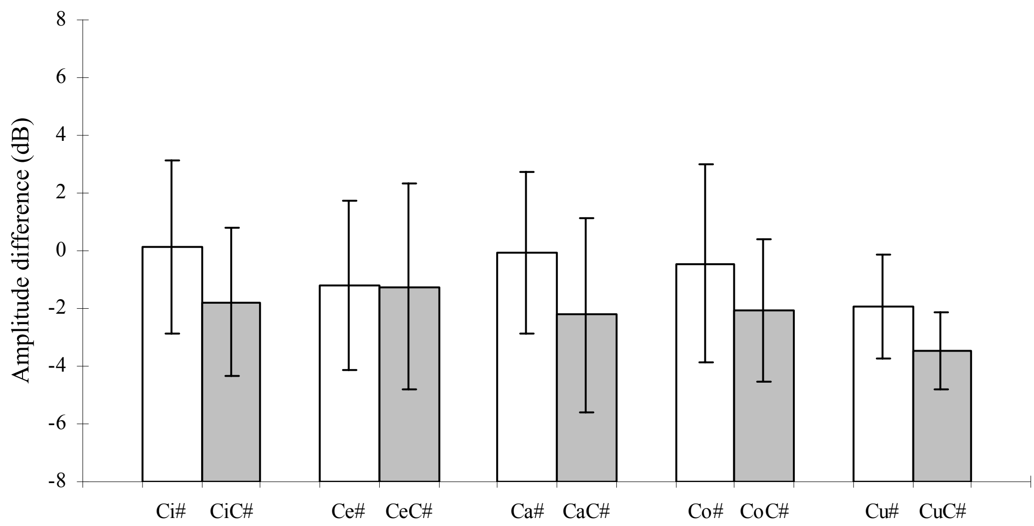

Figure B.9: Differences of the mean amplitude (in dB) of Indonesian /a/ of the frame sentence vs. the mean amplitude of final vowels in open and closed syllables for the bilingual Central Javanese/Indonesian speakers

For these speakers, the mean values of the amplitude difference for vowels in open final syllables are greatest for /i/ and /a/. The mean values for the mid vowels are lower than for /u/. In the closed final syllable case, the mean value is greatest for /e/. They are similar for /i/, /a/, and /o/. The high vowel /u/ has the lowest mean value of amplitude difference. The results here show that the amplitude difference for vowels, whether in open or in closed final syllables, do not follow the expected pattern, whereby high vowels have higher amplitude difference as compared to lower vowels. Statistically, the mean value differences are marginally significant for Ci# vs. Cu# ($p = .04$), Ca# vs. Cu# ($p = .05$), CiC# vs. CuC# ($p = .05$), and CeC# vs. CuC# ($p = .05$).

Comparing the amplitude difference of the same vowel in open vs. closed final syllables, the vowels in the open final syllables have greater mean value as compared to those in the closed ones, except for /e/. The mean value difference for /u/ reaches statistic significance ($p < .05$). Recall that, for the bilingual Central Javanese speakers, high and mid vowels lower and centralize in closed syllables. The formant structures for the Indonesian /a/ in open vs. closed final syllables for these speakers are similar. Given this fact, it seems that here the difference of vowel amplitude difference is not necessarily determined by vowel height, for two reasons: (a) the vowels [e] and [ɛ] have similar amplitude difference, rather than [e], being higher in the acoustic space, having greater amplitude difference than [ɛ]; and (b) the vowel [a] has greater amplitude difference in open final syllables as compared to [a] in closed final syllables.

The lowered and centralized Indonesian high vowels in closed syllables are impressionistically similar to the mid vowels in open syllables, for the bilingual speakers from Central Java. As shown earlier in Figure B.2, /i/ in CiC# overlap in the acoustic space with /e/ in Ce#, and /u/ in CuC# is more centralized but share the same height as /o/ in Co#. If vowel height correlates with vowel relative amplitude, we would expect these vowel pairs to have similar relative amplitude, and consequently similar amplitude difference. However, the result shows that the amplitude difference for /i/ in CiC# is lower than for /e/ in Ce#; in addition, it is lower for /u/ in CuC# than for /o/ in Co#.

Next, I discuss the measurement results of vowel amplitude difference for the bilingual speakers from Eastern Java. The mean values are presented in Figure B.10.

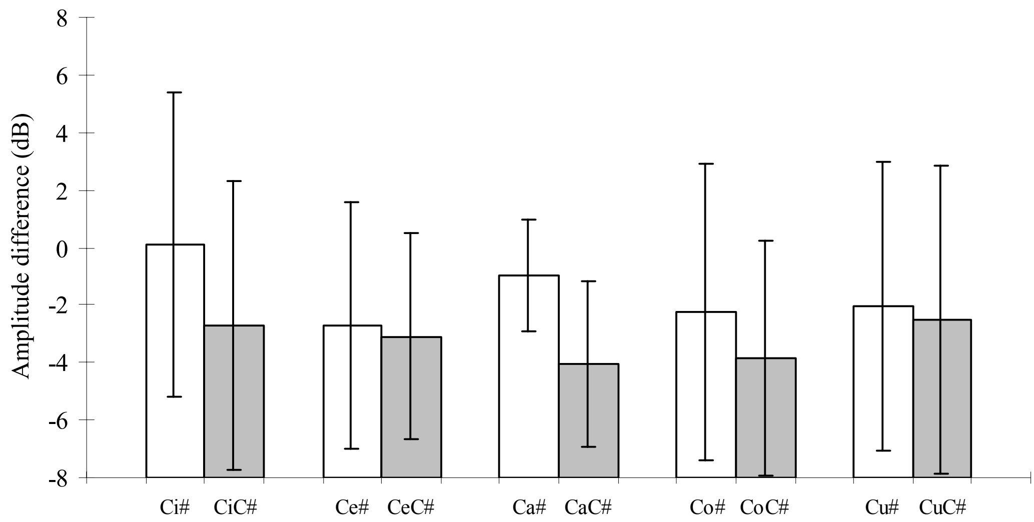

Figure B.10: Differences of the mean amplitude (in dB) of Indonesian /a/ of the frame sentence vs. the mean amplitude of final vowels in open and closed syllables for the bilingual Eastern Javanese/Indonesian speakers

In the open final syllable case, the mean value of amplitude difference for /i/ is greater than it is for /e/. The mean values for /o/ and /u/ are similar. The mean value for /a/ is greater than for the mid vowels and for /u/, but it is lower than it is for /i/. In the closed final syllable case, the mean values for /i/, /e/, and /u/ are similar. The mean value for /a/ is slightly lower than for /o/, which in turn is lower than the mean value for /i/, /e/, and /u/. The amplitude difference mean value for /e/ is slightly lower than it is for /i/ and /u/. Statistically, the mean value differences are not significant for all vowels in the CV# and CVC# cases.

These results suggest that in the open final syllable case, only /i/, having the greatest amplitude difference (thus, implying lowest relative amplitude) follows the expected pattern. In the closed final syllable case, the small mean value differences of amplitude difference among the vowels reflect the expected pattern; however, it is hard to determine to what extent these differences make a difference, since they are quite small.

Comparing vowels in open vs. closed final syllables, the amplitude difference mean values for vowels in the open syllables are greater than for those in the closed syllables. The mean differences are less than 1 dB for /e/ and /u/, and between 1-3 dB for /i/, /a/, and /o/. Statistically, the mean value differences are significant ($p < .05$) only for /a/. As shown in Chapter 3, Figure 3.18, Indonesian vowels in the closed final syllables lower and/or centralize, except for /a/, for the bilingual speakers from East Java. The amplitude measurements in Figure C.10 suggest that, interpreted in terms of relative amplitude, lowered and centralized vowels tend to have greater relative amplitude as compared to their non-lowered counterpart. Note, however, that /a/ in the open and the closed final syllables overlap in the acoustic space for these speakers, and yet /a/ in the open syllable has greater amplitude difference, thus lower relative amplitude, as compared to /a/ in the closed syllable. Comparing vowels that are impressionistically similar, the amplitude difference mean value for /i/ in CiC# is practically the same as the mean value for /e/ in Ce#. This is also the case for /u/ in CuC# vs. /o/ in Co#.

The overall results of amplitude difference measurements across the three speaker groups suggest that vowel height does not necessarily correlate with vowel relative amplitude. One may argue that Indonesian vowels as produced by the bilingual Eastern Javanese/Indonesian speakers do follow the expected tendency, especially in the closed final syllable case. However, the difference is quite small.

B.2.3 Summary

In the Table B.2, I compare the summarized results of the F0 and amplitude difference measurements for Indonesian vowels in final syllables, as produced by the monolingual Indonesian and the bilingual Javanese/Indonesian speakers. Bold prints indicate differences among the speaker groups. These results suggest that there is no systematic correspondence between the alternating final vowels and their fundamental frequency and amplitude difference, in the Indonesian of the monolingual and bilingual speakers.

Table B.2: Summary of the F0 and amplitude difference measurements of Indonesian vowels in the final syllables

	Monolingual Indonesian	Bilingual Central Javanese	Bilingual Eastern Javanese
Fundament-al frequency	No consistent pattern	No consistent pattern	No consistent pattern
Amplitude difference	1. Vowel height does not correspond with the tendency for vowel relative amplitude	1. Vowel height does not correspond with the tendency for vowel relative amplitude	1. Vowel height does not *consistently* correspond with the tendency for vowel relative amplitude

Table B.2 (Continued)

	Monolingual Indonesian	Bilingual Central Javanese	Bilingual Eastern Javanese
	2. Non-lowered vs. lowered vowels: no consistent pattern	**2. Non-lowered vowels tend to have lower relative amplitude as compared to lowered vowels (except for /e/)**	**2. Non-lowered vowels tend to have lower relative amplitude as compared to lowered vowels (except for /e/ and /u/)**
	3. **Impressionistic-ally similar vowels (i.e. /a/) have similar relative amplitude in open vs. closed final syllables**	**3. Impressionistic-ally similar vowels (CiC# vs. Ce#, CaC# vs. Ca#, CuC# vs. Co#) do not have similar relative amplitude**	3. **Impressionistic-ally similar vowels in CiC# vs. Ce# and CuC# vs. Co# have similar relative amplitude, but not CaC# vs. Ca#**

In the next section, I present the F0 and amplitude difference measurements of Indonesian vowels in the penultimate syllable.

B.3 F0 and amplitude difference measurements of penultimate vowels in Indonesian

In this section, I present the F0 and amplitude difference measurements of the Indonesian vowels in the penultimate syllable. The order of presentation is as follows. In § B.3.1, I present the F0 measurements of the Indonesian vowels, and in § B.3.2 the amplitude difference for these vowels. In § B.3.3, I briefly summarize the results.

B.3.1 Vowel fundamental frequency

What we might expect to see here is the general trend whereby high vowels would have high F0 values, and low vowel /a/ would have relatively lowest values. I present the F0 values of vowels in the Indonesian of the monolingual speakers in Figure B.11.

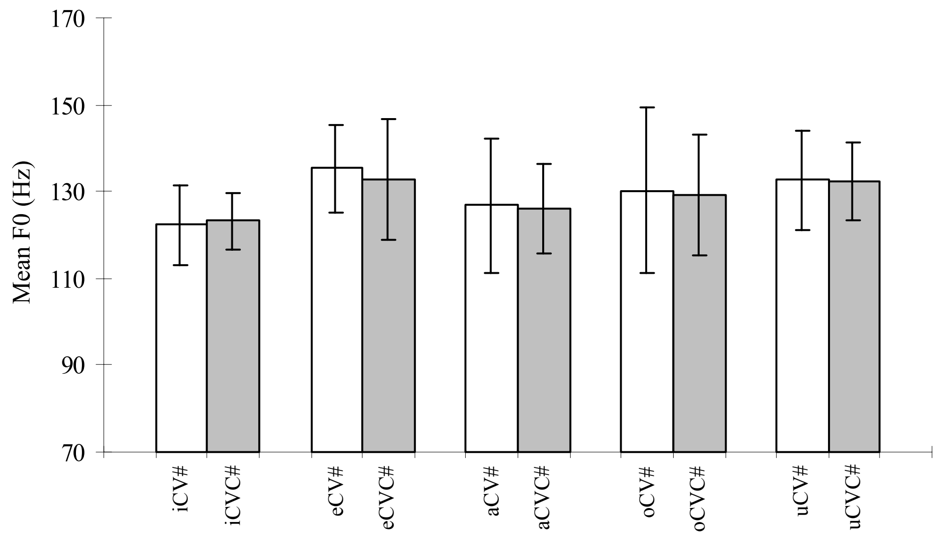

Figure B.11: Mean overall F0 values (in Hz) of Indonesian penultimate vowels preceding open vs. closed final syllables for the monolingual Indonesian speakers

In the open final syllable case, the mean value of /a/ is lower than the mid vowel. It is also lower than the high vowel /u/, but it is greater than /i/. This result is mirrored in the closed final syllable case. For the back and the low vowels, the F0 mean values follow the expected trend: the high vowel /u/ has the highest F0 mean value, the low vowel /a/ has the lowest, and the mean value for the mid vowel /o/ is in between the values for /u/ and /a/. The F0 differences between the penultimate vowels preceding final CVs and those preceding final CVCs do not reach statistic significance.

Next I present the F0 measurement of vowels in the penult by the bilingual speakers from Central Java. The results are shown in Figure B.12.

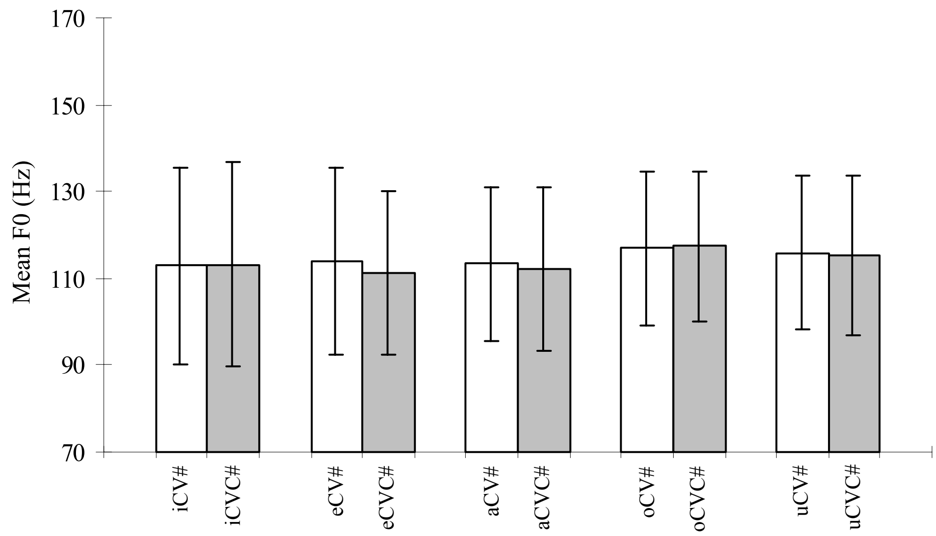

Figure B.12: Mean overall F0 values (in Hz) of Indonesian penultimate vowels preceding open vs. closed syllables for the bilingual Central Javanese/Indonesian speakers

There does not seem to be a pattern of F0 for these vowels. Preceding open final syllables, the mean F0 values are similar for /i/, /e/, and /a/. The mean values for /o/ and /u/ are similar, which in turn are about 3 Hz higher than the mean values for the front and the low vowels. Preceding closed final syllables, the mean values for /i/, /e/, and /a/ are similar. The mean values for /o/ and /u/ are also similar, and these values are about 5 Hz higher than the mean values for the front and low vowels.

The F0 differences between the penultimate vowels preceding final CVs and those preceding final CVCs do not reach statistic significance. This result seems to show that vowel F0 for these speakers do not follow the expected trend.

I turn now to the F0 of vowels in the penult for the bilingual speakers from East Java. The mean F0 values for these speakers are shown in Figure B.13.

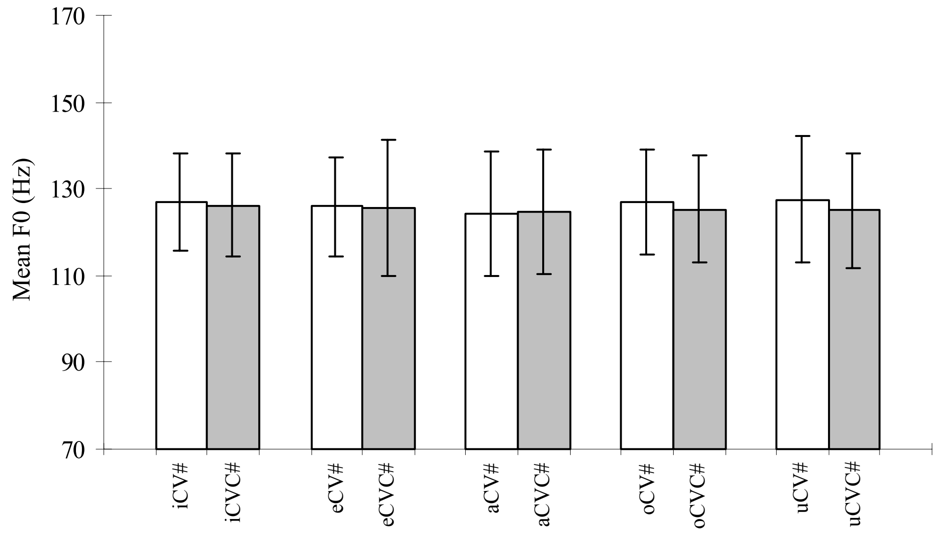

Figure B.13: Mean overall F0 values (in Hz) of Indonesian penultimate vowels preceding open vs. closed syllables for the bilingual Eastern Javanese/Indonesian speakers

In the open final syllable case, the mean F0 values are similar for all vowels, with the difference between the greatest and the lowest values of 3 Hz. In the closed final syllable case, the mean F0 values are also similar for all vowels, with the highest and lowest value difference of

2 Hz. The F0 differences between the penultimate vowels preceding final CVs and those preceding final CVCs do not reach statistic significance.

The overall measurement results of F0 here seem to suggest that the F0 of vowels in the penult across the three speaker groups does not follow the general expected F0 pattern of vowels. It is interesting to note that this is also the case with the Indonesian vowels in the final position, for all three speaker groups (see Chapter 3, § 3.5.3). The lack of F0 pattern of the Indonesian vowels may be due to these particular speakers, thus not necessarily a widespread phenomenon, and/or to the specific set of analyzed words.

B.3.2 Vowel amplitude

As briefly discussed earlier, there has been no reported case where vowel contrast (whether or not it involves vowel quality) is expressed acoustically in the amplitude. The correlation between vowel height and vowel amplitude is thus arguably a phonetic effect. The examination of vowel amplitude carried out here is to compare penultimate vowels of different heights.

Recall that since there is a great deal of variation in the production of vowels, the amplitude values presented here are not the raw values; rather, they are the difference between the relative amplitude of the anchor vowel /a/ and a target vowel. Using this method of comparison, we would predict that, if vowel height corresponds with vowel amplitude, higher vowels would tend to have greater amplitude difference as compared to lower vowels. In the realm of vowel relative amplitude, this would translate to the tendency for higher vowels as having lower relative amplitude when compared to lower vowels. The mean values of amplitude difference of the Indonesian vowels in the penult, as produced by the monolingual speakers, are presented in Figure B.14.

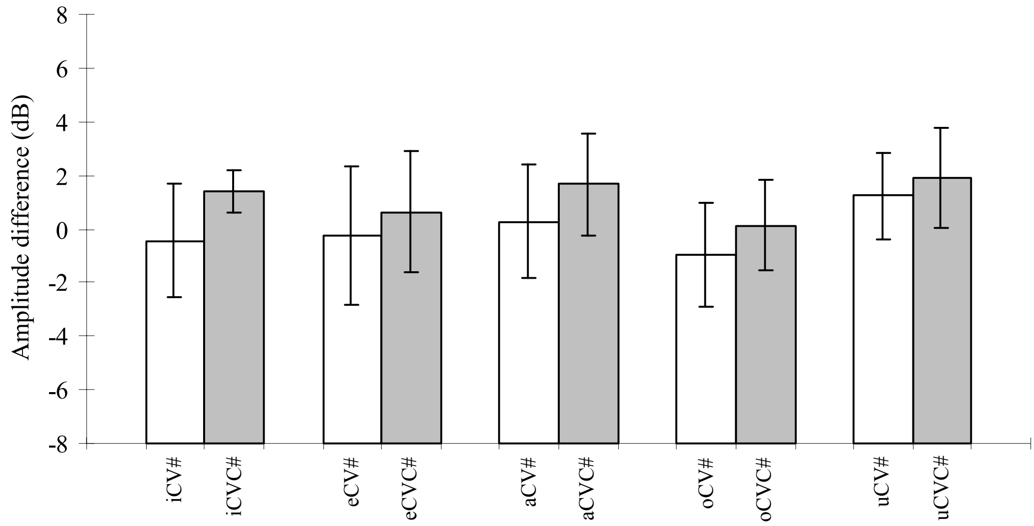

Figure B.14: Differences of the mean amplitude of Indonesian /a/ of the frame sentence vs. the mean amplitude (in dB) of penultimate vowels preceding open and closed final syllables, for the monolingual Indonesian speakers

In the case of vowels in the penult followed by an open final syllable, /u/ has the greatest mean value of amplitude difference. The mean value for /a/ is slightly lower than for /u/. For /i/ and for /e/, the mean values are similar, which in turn are lower than the mean value for /a/. The amplitude difference mean value for /o/ is the smallest. In the case of vowels followed by a closed final syllable, /i/, /a/, and /u/ have similar mean value of amplitude difference. The mean values for /e/ and for /o/, which are smaller than for the high and the low vowels, are similar. Statistically, the mean value differences are significant ($p < .05$) for Co# vs. Cu#, CiC# vs. CoC#, and CoC# vs. CuC#; they are marginally significant ($p = .04$) for Ci# vs. Cu# and CaC# vs. CoC#. The results here seem to indicate that vowel height does not correlate with vowel amplitude.

Comparing vowels preceding open vs. closed final syllables, those preceding open syllables have lower mean value of amplitude difference as compared to those preceding closed syllables. Statistically, the mean value differences are significant for /i/. This result seems to suggest that the structure of the final syllable influences the amplitude difference of vowels (and thus the relative amplitude of vowels), and that vowel height does not play a role.

Next, I analyze the results of amplitude measurements of the vowels in the penult, as produced by the bilingual Central Javanese/Indonesian speakers. The results are shown in Figure B.15.

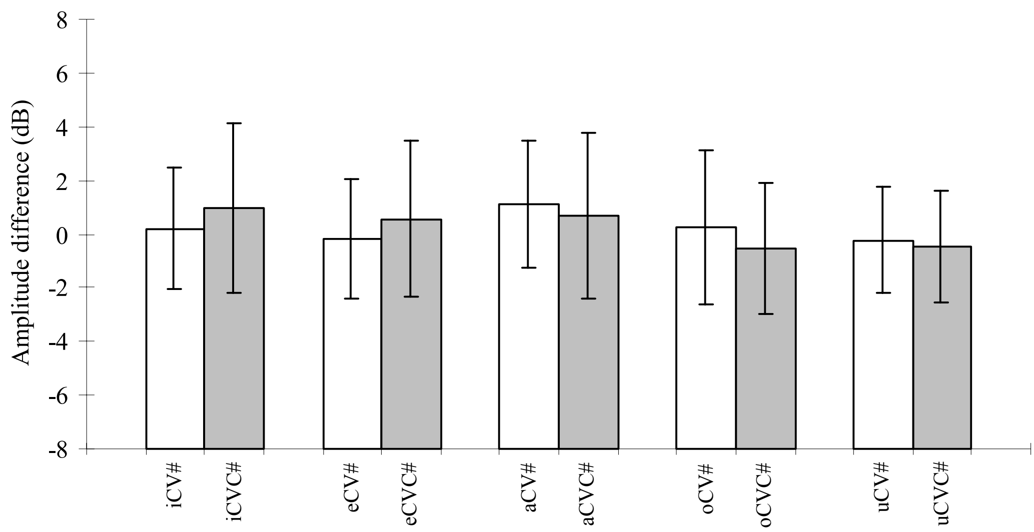

Figure B.15: Differences of the mean amplitude of Indonesian /a/ of the frame sentence vs. the mean amplitude (in dB) of penultimate vowels preceding open and closed final syllables, for the bilingual Central Javanese/Indonesian speakers

In the case of vowels preceding the open final syllables, the mean values of amplitude difference for /i/, /e/, and /o/ are similar. The mean value for /a/ is greater and for /u/ is slightly lower as compared to the mean values for /i/, /e/, and /o/. In the case of vowels preceding the closed final syllables, the mean values for /i/, /e/, and /a/ are similar. They are lower for /o/ and for /u/ than they are for /i/, /e/, and /a/. None of the mean value differences reaches statistic significance. The results here indicate that the correlation between vowel height and vowel amplitude is not borne out.

Comparing vowels preceding the open vs. closed final syllables, the mean values of amplitude difference for /i/ and /e/ are lower preceding the open final syllables than preceding the closed ones. They are greater preceding the open vs. closed final syllables, for /a/, /o/, and /u/. None of the mean value differences reaches statistic significance. These results suggest that there is no consistent pattern with respect to the correlation between vowel height and vowel amplitude, since the similar vowels (iCV# vs. iCVC#, aCV# vs. aCVC#, and uCV# vs. uCVC#) have different, rather than similar, amplitude difference. In addition, lowered vowels do not necessarily have lower amplitude difference (or greater relative amplitude), as compared to their non-lowered counterpart (i.e. the amplitude difference for eCVC# is greater than for eCV#, contrary to the expected tendency).

Next, the amplitude difference measurements of penultimate vowels as produced by the bilingual speakers from East Java are presented. The results are shown in Figure B.16.

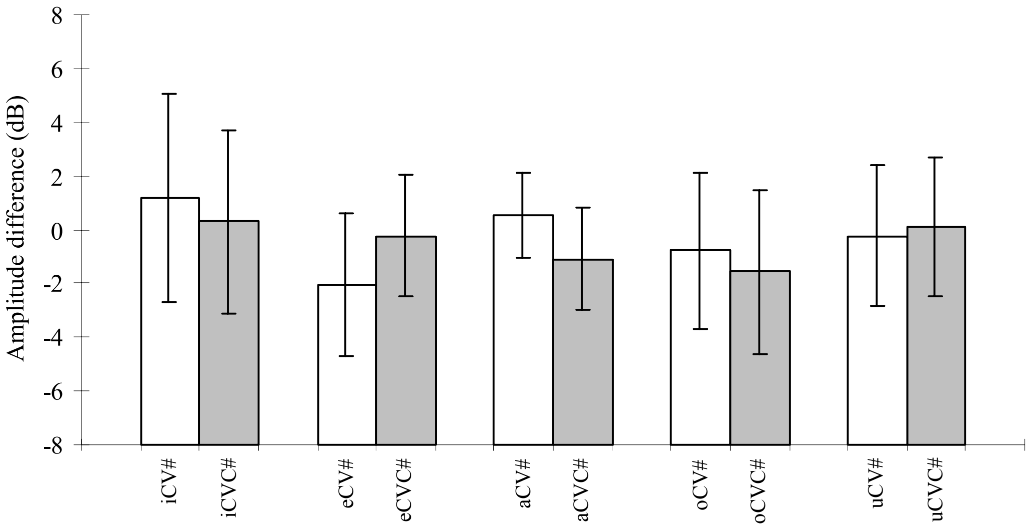

Figure B.16: Differences of the mean amplitude of Indonesian /a/ of the frame sentence vs. the mean amplitude (in dB) of penultimate vowels preceding open and closed final syllables, for the bilingual Eastern Javanese/Indonesian speakers

In the case of penultimate vowels preceding the open final syllables, the amplitude difference mean values for the high vowels are greater than for the lower vowels. The difference is greater for /i/ vs. /e/ than it is for /u/ vs. /o/. The mean value for the low vowel is greater than for the mid vowels. In the case of penultimate vowels preceding the closed final syllables, the mean value for /i/ is the greatest. These mean values of amplitude difference are similar for /e/ and /u/, and they are the lowest for /a/ and /o/. Statistically, the mean value differences are significant ($p < .05$) for Ci# vs. Ce# and Ce# vs. Ca#. These results suggest that while the high vowels tend to have greater amplitude difference mean value, thus lower relative amplitude, as compared to the mid vowels, the low vowel does not follow this tendency.

Comparing vowels preceding open vs. closed final syllables, the mean values in the open final syllable case are greater than in the closed final syllable case for /i/, /o/, and /a/. Statistically, the mean value differences are significant for /a/. Recall that, as presented earlier in Chapter 3, Figure 3.24, the mean F1/F2 values of /a/ preceding open and that preceding closed final syllables overlap in the acoustic space. Thus, we would expect their relative amplitude to be similar; however, the result here shows that they are not. Recall also that impressionistically, vowel harmony occurs to the high and mid vowels in the penult for the Eastern Javanese speakers. The formant structures presented in Figure 3.24 show that the penultimate vowels /i/, /e/, and /o/ lower when the following final syllable is closed, suggesting that vowel harmony is realized acoustically for these vowels. Thus, the mean values of amplitude difference of these vowels in the closed final syllable case are expected to be lower than in the open final syllable case. This is the case for /i/ and /o/, but not for /e/. Based on these results, one may conclude that for the bilingual Eastern Javanese speakers, the relative amplitude of Indonesian vowels in the penult do not always show correlation with the height of these vowels.

To briefly summarize the overall results of vowel amplitude difference in this section, the Indonesian vowels in the penult as produced by the monolingual and bilingual speakers do not systematically show the expected pattern of vowel amplitude difference, whereby high vowels tend to have greater amplitude difference, thus lower relative amplitude, than lower vowels. The acoustic findings across the three speaker groups show that high vowels may have lower, similar, and greater amplitude difference, as compared to lower vowels; the same findings are the case of the lower vowels.

B.3.3 Summary

In Table B.3, I summarize the measurement results of F0 and amplitude differences for the penultimate vowels in the Indonesian of the monolinguals and the bilingual speakers.

Table B.3: Summary of the F0 and amplitude difference measurements of Indonesian vowels in the penultimate syllables

	Monolingual Indonesian	Bilingual Central Javanese	Bilingual Eastern Javanese
Fundament-al frequency	Vowel F0 does not follow the expected pattern	Vowel F0 does not follow the expected pattern	Vowel F0 does not follow the expected pattern
Amplitude difference	Vowel height does not always correspond with the expected pattern of vowel amplitude	Vowel height does not always correspond with the expected pattern of vowel amplitude	Vowel height does not always correspond with the expected pattern of vowel amplitude

As suggested by the measurements here, the expected correspondence between vowel height and vowel fundamental frequency and amplitude difference is not acoustically realized in the Indonesian vowels in the penultimate syllable.

APPENDIX C: ACOUSTIC VALUES FOR THE VOWEL ALTERNATION STUDY

This appendix presents the results of the acoustic measurements relevant to vowel alternation in Javanese and Indonesian (Chapter 3), by the individual speakers. The list consists of the mean values across four repetitions for each speaker, the mean values across all speakers, and the standard deviations of the first and second formants (in Hz), overall fundamental frequency (in Hz), duration (in ms), and amplitude (in dB). The values for the Javanese vowels by the Central Javanese speakers are presented in § C.1, and those by the Eastern Javanese speakers are presented in § C.2. The values for the Indonesian vowels are presented in § C.3 for the monolingual speakers, in § C.4 for the bilingual speakers from Central Javanese, and in § C.5 for the bilingual speakers from East Java.

C.1 Javanese vowels by the Central Javanese speakers

In § C.1.1, I present values for the Javanese vowels in CVCV words and in § C.1.2, the values for vowels in CVCVC words.

C.1.1 Javanese vowels in CVCV words

1. /i/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	340 (12)	2414 (75)	88 (7)	67 (5)	0.26 (1.4)
CJ_m2	336 (4)	2176 (95)	132 (1)	86 (4)	1.47 (1.8)
CJ_m3	315 (15)	2179 (48)	111 (4)	79 (3)	2.6 (0.5)
Mean	**330 (15)**	**2256 (135)**	**110 (19)**	**78 (9)**	**0.46 (2.2)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	335 (12)	2344 (27)	102 (8)	89 (21)	-1.9 (0.7)
CJ_m2	300 (18)	2224 (76)	138 (3)	126 (18)	-1.6 (1.6)
CJ_m3	318 (11)	2196 (40)	110 (5)	111 (10)	2.2 (1.3)
Mean	**318** (19)	**2255** (82)	**116 (17)**	**109 (22)**	**0.4 (2.3)**

2. /e/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	406 (10)	2002 (93)	80 (8)	89 (4)	0.9 (1.7)
CJ_m2	475 (29)	1946 (46)	135 (2)	97 (6)	1.3 (0.9)
CJ_m3	434 (14)	1984 (48)	114 (3)	100 (9)	1.5 (0.9)
Mean	**438 (15)**	**1977 (135)**	**109 (24)**	**95 (8)**	**1.2 (1.1)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	422 (21)	1950 (60)	124 (7)	109 (13)	-3.1 (2.4)
CJ_m2	452 (34)	1977 (57)	142 (3)	145 (14)	1.8 (1.1)
CJ_m3	432 (16)	1950 (21)	115 (3)	128 (15)	1.8 (1.1)
Mean	**435 (26)**	**1959 (47)**	**127 (13)**	**127 (20)**	**0.2 (2.8)**

3. /a/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	514 (19)	959 (47)	91 (5)	107 (6)	2.7 (1.5)
CJ_m2	598 (4)	1116 (28)	136 (2)	107 (6)	0.6 (1.7)
CJ_m3	560 (3)	1044 (24)	112 (2)	104 (10)	-1.1 (0.8)
Mean	**557 (37)**	**1039 (74)**	**113 (20)**	**106 (7)**	**0.7 (2.1)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	511 (29)	985 (118)	91 (5)	100 (3)	0.9 (1.4)
CJ_m2	594 (8)	1094 (26)	136 (2)	147 (3)	0.7 (1.1)
CJ_m3	545 (7)	1052 (35)	112 (2)	111 (3)	0.6 (0.9)
Mean	**550 (39)**	**1044 (81)**	**113 (20)**	**119 (21)**	**0.7 (1.1)**

4. /o/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	381 (3)	859 (34)	90 (1)	97 (9)	0.3 (2.9)
CJ_m2	442 (20)	1114 (66)	136 (9)	92 (7)	-0.4 (2.4)
CJ_m3	464 (13)	1037 (27)	115 (7)	107 (7)	2.7 (1.4)
Mean	**429 (39)**	**1003 (119)**	**114 (21)**	**98 (10)**	**0.9 (2.5)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	414 (17)	889 (53)	118 (3)	121 (16)	-3.7 (3.5)
CJ_m2	413 (7)	1090 (18)	139 (11)	129 (20)	-0.7 (1.5)
CJ_m3	456 (7)	1028 (61)	115 (4)	116 (20)	2.1 (0.8)
Mean	**428 (23)**	**1002 (98)**	**124 (13)**	**122 (18)**	**-0.7 (3.2)**

5. /u/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	331 (22)	1151 (58)	91 (8)	109 (13)	3.5 (1.4)
CJ_m2	309 (13)	1230 (64)	130 (3)	95 (12)	-0.7 (0.8)
CJ_m3	386 (34)	1062 (37)	112 (3)	117 (4)	3.8 (1.1)
Mean	**342 (40)**	**1148 (98)**	**111 (17)**	**107 (14)**	**2.2 (2.4)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	320 (27)	1310 (117)	116 (9)	109 (22)	0.1 (0.5)
CJ_m2	307 (8)	1196 (148)	139 (9)	114 (20)	-1.9 (0.6)
CJ_m3	383 (26)	1051 (58)	112 (2)	125 (11)	3.3 (0.9)
Mean	**337 (40)**	**1186 (127)**	**122 (14)**	**116 (18)**	**0.5 (2.3)**

C.1.2 Javanese vowels in CVCVC words

1. /i/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	338 (8)	2348 (102)	85 (7)	62 (4)	-0.3 (1.1)
CJ_m2	313 (24)	2092 (24)	128 (3)	74 (6)	0.3 (1.3)
CJ_m3	317 (16)	2142 (66)	110 (1)	68 (11)	3.3 (0.9)
Mean	**323 (19)**	**2194 (79)**	**108 (19)**	**68 (9)**	**1.1 (1.9)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	437 (6)	1932 (29)	101 (12)	56 (6)	-2.8 (1.2)
CJ_m2	430 (36)	1952 (29)	139 (1)	71 (7)	-1.1 (1.5)
CJ_m3	429 (32)	1937 (28)	115 (3)	72 (9)	1.4 (0.3)
Mean	**432 (25)**	**1940 (27)**	**118 (18)**	**66 (10)**	**-0.8 (2.1)**

2. /e/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	623 (10)	1752 (18)	84 (6)	93 (6)	2.3 (1.6)
CJ_m2	624 (16)	1687 (16)	132 (5)	94 (4)	0.8 (1.9)
CJ_m3	576 (12)	1585 (25)	111 (1)	99 (10)	1.7 (0.9)
Mean	**607 (26)**	**1674 (74)**	**109 (21)**	**95 (7)**	**1.6 (1.5)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	579 (44)	1692 (24)	128 (5)	82 (8)	-2 (2)
CJ_m2	616 (11)	1592 (23)	135 (4)	96 (6)	0.2 (2.2)
CJ_m3	562 (9)	1571 (31)	112 (2)	99 (6)	1.8 (0.7)
Mean	**574 (34)**	**1644 (60)**	**125 (11)**	**92 (10)**	**0.01 (2.3)**

3. /a/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	894 (43)	1465 (7)	84 (7)	104 (10)	5.6 (0.4)
CJ_m2	722 (14)	1341 (31)	129 (3)	96 (4)	2 (1.3)
CJ_m3	701 (18)	1309 (19)	108 (3)	101 (10)	2.3 (0.9)
Mean	**772 (94)**	**1372 (73)**	**107 (20)**	**100 (8)**	**3.3 (1.9)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	699 (38)	1431 (61)	105 (12)	72 (12)	0.2 (1.2)
CJ_m2	648 (37)	1378 (20)	138 (4)	66 (6)	1.6 (0.9)
CJ_m3	697 (32)	1369 (24)	110 (4)	84 (4)	2.2 (0.7)
Mean	**681 (41)**	**1393 (46)**	**118 (17)**	**74 (11)**	**1.3 (1.2)**

4. /o/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	496 (54)	942 (90)	90 (6)	149 (18)	4.6 (0.9)
CJ_m2	589 (12)	1143 (10)	132 (3)	117 (16)	-0.6 (1.5)
CJ_m3	576 (20)	1065 (22)	115 (4)	116 (6)	0.3 (0.3)
Mean	**554 (53)**	**1050 (99)**	**112 (19)**	**128 (21)**	**1.4 (2.5)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	550 (34)	1109 (71)	116 (10)	79 (2)	-0.6 (0.9)
CJ_m2	582 (14)	1165 (28)	135 (3)	90 (15)	-2 (1.9)
CJ_m3	571 (13)	1055 (30)	112 (4)	102 (11)	-0.5 (0.5)
Mean	**568 (25)**	**1110 (63)**	**121 (12)**	**90 (14)**	**-1.1 (1.3)**

5. /u/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	327 (22)	1188 (58)	91 (8)	94 (9)	2.5 (1.2)
CJ_m2	298 (13)	1241 (64)	136 (3)	91 (5)	1.5 (1.9)
CJ_m3	382 (34)	1150 (37)	112 (4)	119 (8)	4.1 (1.4)
Mean	**336 (42)**	**1193 (63)**	**113 (20)**	**101 (15)**	**2.7 (1.8)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	424 (14)	1313 (47)	107 (14)	66 (8)	-1.8 (1.2)
CJ_m2	417 (9)	1309 (49)	145 (4)	84 (7)	-1.9 (1.7)
CJ_m3	438 (22)	1242 (83)	114 (2)	91 (12)	1.9 (1.2)
Mean	**426 (17)**	**1288 (65)**	**122 (19)**	**81 (14)**	**-0.6 (2.2)**

C.2 Javanese vowels by the Eastern Javanese speakers

In § C.2.1, I present the values for the Javanese vowels in CVCV words and in § C.2.2, the values for vowels in CVCVC words

C.2.1 Javanese vowels in CVCV words

1. /i/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	387 (15)	2057 (189)	131 (1)	63 (7)	1.1 (0.6)
EJ_m2	353 (16)	2143 (98)	137 (2)	61 (3)	0.5 (0.9)
EJ_m3	367 (25)	1905 (59)	113 (2)	95 (4)	-2.5 (1.2)
Mean	**369 (22)**	**2035 (161)**	**128 (10)**	**73 (16)**	**0.4 (1.8)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	389 (9)	2161 (89)	131 (2)	89 (17)	0.9 (1.1)
EJ_m2	384 (19)	1982 (48)	138 (2)	71 (6)	-0.1 (0.5)
EJ_m3	346 (8)	1917 (24)	113 (1)	130 (4)	-3.2 (0.5)
Mean	**373 (24)**	**2020 (121)**	**129 (11)**	**97 (28)**	**-1 (2.1)**

2. /e/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	440 (10)	1983 (107)	130 (2)	72 (11)	1.4 (0.4)
EJ_m2	402 (11)	1943 (61)	137 (1)	55 (1)	0.3 (1.4)
EJ_m3	426 (8)	1834 (40)	112 (2)	103 (5)	-4.2 (1.2)
Mean	**423 (19)**	**1920 (94)**	**126 (11)**	**77 (22)**	**-0.8 (2.7)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	420 (7)	1968 (45)	130 (2)	96 (4)	0.6 (0.6)
EJ_m2	414 (36)	1902 (89)	136 (2)	70 (7)	0.2 (1.6)
EJ_m3	428 (16)	1848 (47)	113 (2)	145 (8)	-4.2 (1.1)
Mean	**421 (22)**	**1906 (77)**	**126 (11)**	**104 (33)**	**-1.2 (2.5)**

3. /a/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp (sd)
EJ_m1	573 (27)	1179 (65)	135 (2)	100 (15)	-0.9 (1.2)
EJ_m2	559 (13)	1064 (9)	146 (4)	69 (5)	-1.4 (0.8)
EJ_m3	527 (5)	1073 (48)	108 (2)	133 (8)	-4.2 (1.3)
Mean	**553 (25)**	**1105 (69)**	**130 (17)**	**101 (29)**	**-2.1 (1.8)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	563 (10)	1214 (31)	138 (3)	101 (7)	-0.9 (0.8)
EJ_m2	532 (40)	1111 (72)	160 (6)	120 (15)	-2.4 (0.9)
EJ_m3	515 (10)	1084 (39)	108 (1)	129 (19)	-4.4 (1.2)
Mean	**536 (30)**	**1136 (74)**	**135 (23)**	**117 (18)**	**-2.5 (1.8)**

4. /o/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	455 (14)	1428 (61)	135 (5)	68 (5)	3.3 (1.2)
EJ_m2	420 (12)	1231 (120)	141 (5)	68 (15)	-0.9 (1.3)
EJ_m3	414 (10)	1075 (27)	113 (2)	114 (6)	-3.4 (1.6)
Mean	**430 (22)**	**1245 (167)**	**130 (13)**	**84 (24)**	**-0.4 (3.1)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	462 (18)	1500 (7)	130 (2)	79 (3)	1.9 (2.3)
EJ_m2	410 (11)	1360 (85)	140 (4)	67 (17)	-0.7 (1.1)
EJ_m3	422 (19)	1272 (30)	115 (2)	134 (12)	-4.3 (1.1)
Mean	**431 (28)**	**1377 (109)**	**128 (11)**	**93 (18)**	**-0.9 (3.1)**

5. /u/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp (sd)
EJ_m1	387 (12)	1420 (73)	132 (1)	87 (9)	3.6 (0.7)
EJ_m2	378 (21)	1464 (92)	145 (7)	64 (17)	0.1 (1.1)
EJ_m3	356 (7)	1466 (37)	111 (2)	95 (15)	0.2 (1.7)
Mean	**374 (19)**	**1450 (68)**	**129 (15)**	**82 (19)**	**1.1 (2)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp (sd)
EJ_m1	378 (15)	1387 (129)	134 (2)	103 (18)	4.6 (1.5)
EJ_m2	368 (19)	1387 (132)	146 (8)	68 (12)	-0.9 (2.2)
EJ_m3	367 (10)	1380 (79)	116 (5)	123 (8)	-2.7 (2.3)
Mean	**371 (15)**	**1384 (105)**	**132 (14)**	**98 (27)**	**0.03 (3.7)**

C.2.2 Javanese vowels in CVCVC words

1. /i/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	429 (14)	1977 (119)	126 (4)	72 (8)	1.1 (1.5)
EJ_m2	408 (12)	1946 (18)	138 (3)	65 (3)	0.5 (0.7)
EJ_m3	411 (7)	1764 (25)	108 (2)	85 (13)	-3.1 (0.9)
Mean	**416 (14)**	**1896 (117)**	**124 (13)**	**74 (12)**	**-0.5 (2.1)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	444 (12)	1842 (87)	127 (1)	44 (10)	0.8 (1.3)
EJ_m2	428 (5)	1959 (15)	137 (5)	41 (6)	-1.1 (2.3)
EJ_m3	437 (12)	1700 (29)	112 (2)	55 (6)	-4.8 (1.5)
Mean	**436 (12)**	**1834 (121)**	**126 (11)**	**47 (9)**	**-1.6 (2.9)**

2. /e/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	607 (12)	1793 (49)	132 (1)	83 (8)	-0.02 (1.4)
EJ_m2	515 (23)	1720 (32)	129 (5)	62 (6)	0.8 (1.3)
EJ_m3	543 (8)	1571 (28)	110 (1)	107 (7)	-5.9 (0.3)
Mean	**555 (43)**	**1695 (102)**	**124 (11)**	**84 (21)**	**-1.7 (3.3)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp (sd)
EJ_m1	593 (29)	1741 (29)	133 (3)	87 (6)	-0.4 (1.7)
EJ_m2	520 (13)	1595 (29)	132 (3)	55 (3)	1.2 (0.5)
EJ_m3	541 (11)	1510 (18)	112 (1)	73 (9)	-7 (0.9)
Mean	**551 (37)**	**1615 (102)**	**126 (11)**	**74 (15)**	**-2 (3.4)**

3. /a/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp (sd)
EJ_m1	682 (40)	1498 (25)	128 (2)	80 (4)	-2.3 (0.6)
EJ_m2	588 (75)	1477 (135)	132 (7)	71 (9)	3.8 (0.8)
EJ_m3	671 (37)	1266 (13)	103 (4)	107 (12)	-3.3 (0.9)
Mean	**647 (65)**	**1414 (131)**	**121 (14)**	**86 (18)**	**-0.7 (3.4)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	664 (20)	1454 (22)	130 (3)	62 (4)	-2 (1.2)
EJ_m2	547 (19)	1440 (27)	134 (4)	40 (6)	3.1 (1.3)
EJ_m3	609 (28)	1402 (27)	107 (3)	55 (3)	-3.2 (0.7)
Mean	**607 (54)**	**1432 (32)**	**124 (13)**	**52 (10)**	**-0.9 (3)**

4. /o/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	576 (23)	1162 (93)	132 (1)	86 (20)	0.2 (0.7)
EJ_m2	528 (21)	1095 (44)	134 (2)	105 (25)	-1.9 (0.6)
EJ_m3	526 (19)	984 (74)	108 (1)	137 (17)	-3.6 (1.5)
Mean	**543 (31)**	**1080 (101)**	**125 (12)**	**109 (29)**	**-1.6 (1.9)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp (sd)
EJ_m1	573 (11)	1195 (23)	131 (1)	71 (10)	-0.9 (1)
EJ_m2	534 (13)	1163 (52)	135 (3)	61 (5)	-3.8 (0.7)
EJ_m3	517 (11)	1065 (94)	110 (1)	85 (7)	-5.9 (0.6)
Mean	**542 (27)**	**1141 (81)**	**126 (12)**	**73 (12)**	**-3.3 (2.3)**

5. /u/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	381 (21)	1533 (30)	132 (2)	78 (10)	1.9 (1.2)
EJ_m2	414 (16)	1491 (109)	142 (2)	69 (12)	1.6 (2.2)
EJ_m3	390 (9)	1510 (61)	112 (2)	91 (9)	-0.6 (0.7)
Mean	**395 (21)**	**1511 (69)**	**129 (13)**	**79 (13)**	**0.9 (1.8)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	359 (16)	1621 (12)	127 (2)	45 (6)	2.6 (2.2)
EJ_m2	435 (8)	1447 (45)	148 (5)	49 (4)	-1.4 (2.8)
EJ_m3	432 (14)	1439 (40)	116 (4)	63 (6)	-4 (1.4)
Mean	**409 (39)**	**1502 (93)**	**130 (14)**	**53 (10)**	**-0.9 (3.2)**

C.3 Indonesian vowels by the monolingual speakers

In § C.3.1, I present the values for the Javanese vowels in CVCV words and in § C.3.2, the values for vowels in CVCVC words.

C.3.1 Indonesian vowels in CVCV words

/i/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	314 (13)	2273 (95)	112 (4)	75 (6)	-0.8 (1.4)
IM_m2	277 (7)	2136 (34)	131 (7)	84 (7)	-1.9 (2.4)
IM_m3	351 (8)	2106 (12)	124 (2)	98 (4)	1.4 (1.2)
Mean	**314 (33)**	**2172 (93)**	**122 (9)**	**86 (11)**	**-0.4 (2.1)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	298 (27)	2378 (41)	109 (5)	107 (17)	-0.6 (1.2)
IM_m2	274 (10)	2105 (69)	125 (3)	101 (13)	0.1 (2)
IM_m3	337 (6)	2166 (14)	125 (4)	154 (9)	1.9 (1.4)
Mean	**303 (31)**	**2216 (130)**	**120 (9)**	**120 (28)**	**0.5 (1.8)**

/e/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	394 (11)	1999 (14)	125 (7)	77 (10)	-0.4 (0.7)
IM_m2	443 (30)	1680 (73)	136 (3)	93 (9)	-3 (1.1)
IM_m3	503 (32)	1644 (34)	145 (7)	118 (4)	2.7 (0.9)
Mean	**447 (52)**	**1774 (172)**	**135 (10)**	**96 (19)**	**-0.3 (2.6)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	388 (14)	2006 (78)	119 (3)	97 (7)	-0.1 (0.8)
IM_m2	468 (38)	1688 (48)	109 (6)	138 (23)	-1.8 (0.9)
IM_m3	529 (13)	1697 (17)	143 (13)	192 (14)	3.2 (1)
Mean	**462 (64)**	**1797 (162)**	**124 (16)**	**142 (43)**	**0.4 (2.3)**

/a/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	625 (8)	1547 (34)	113 (7)	93 (7)	-0.1 (1.6)
IM_m2	594 (15)	1255 (49)	122 (3)	108 (3)	-1.6 (1)
IM_m3	669 (22)	1450 (17)	146 (6)	142 (13)	2.5 (0.9)
Mean	**629 (35)**	**1417 (131)**	**127 (15)**	**114 (23)**	**0.3 (2.1)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	593 (33)	1498 (28)	107 (4)	97 (5)	1.1 (2.1)
IM_m2	586 (8)	1268 (10)	123 (5)	128 (8)	-1.7 (1.8)
IM_m3	702 (6)	1430 (22)	146 (7)	230 (17)	1.9 (0.8)
Mean	**627 (59)**	**1399 (103)**	**125 (17)**	**152 (60)**	**0.4 (2.2)**

/o/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	414 (23)	1413 (37)	107 (7)	77 (11)	-1 (3.3)
IM_m2	473 (15)	1504 (68)	134 (3)	88 (14)	-1.2 (1.1)
IM_m3	447 (7)	1191 (38)	150 (5)	127 (1)	-0.7 (1.2)
Mean	**445 (29)**	**1369 (121)**	**130 (19)**	**97 (24)**	**-0.9 (1.9)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	431 (12)	1383 (15)	106 (3)	89 (3)	-0.5 (3.1)
IM_m2	474 (22)	1092 (74)	124 (7)	73 (9)	-2.8 (1)
IM_m3	456 (8)	1107 (30)	153 (7)	180 (14)	-0.9 (1)
Mean	**454 (23)**	**1194 (146)**	**128 (21)**	**114 (50)**	**-1.4 (2.1)**

/u/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	346 (10)	1523 (63)	123 (2)	65 (7)	2.7 (0.4)
IM_m2	350 (14)	1379 (73)	130 (3)	60 (6)	-0.1 (1.7)
IM_m3	334 (9)	1607 (47)	146 (9)	91 (8)	1.1 (1.1)
Mean	**343 (12)**	**1503 (98)**	**133 (11)**	**72 (16)**	**1.2 (1.6)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	328 (12)	1469 (52)	114 (3)	84 (16)	2.6 (1.1)
IM_m2	344 (13)	1091 (60)	111 (8)	137 (9)	1.4 (1.2)
IM_m3	374 (21)	1211 (91)	148 (8)	103 (13)	-0.2 (0.8)
Mean	**348 (25)**	**1257 (176)**	**124 (19)**	**108 (26)**	**1.3 (1.5)**

C.3.2 Indonesian vowels in CVCVC words

/i/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	334 (2)	2190 (47)	115 (4)	50 (7)	0.8 (0.6)
IM_m2	351 (9)	1909 (40)	127 (3)	53 (7)	1.8 (0.3)
IM_m3	369 (4)	2090 (28)	127 (2)	89 (5)	1.5 (1)
Mean	**348 (16)**	**2071 (106)**	**123 (7)**	**64 (19)**	**1.4 (0.8)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	378 (6)	2119 (37)	111 (16)	50 (4)	-1.5 (0.7)
IM_m2	376 (6)	1936 (59)	128 (20)	39 (4)	-0.7 (0.4)
IM_m3	379 (6)	2066 (15)	130 (2)	105 (6)	-0.3 (0.9)
Mean	**378 (5)**	**2040 (89)**	**122 (17)**	**64 (30)**	**-0.8 (0.8)**

/e/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	496 (38)	1715 (81)	119 (4)	78 (8)	1 (1.2)
IM_m2	510 (8)	1600 (24)	130 (2)	95 (8)	-1.9 (0.2)
IM_m3	524 (12)	1603 (30)	146 (14)	106 (7)	2.8 (1.3)
Mean	**511 (22)**	**1632 (67)**	**133 (14)**	**94 (14)**	**0.6 (2.2)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	544 (9)	1733 (32)	112 (3)	77 (10)	0.9 (1.4)
IM_m2	528 (12)	1548 (6)	126 (4)	82 (3)	-3.1 (0.3)
IM_m3	529 (15)	1661 (28)	153 (11)	102 (10)	0.8 (0.7)
Mean	**527 (13)**	**1653 (81)**	**132 (19)**	**88 (13)**	**-0.4 (2.2)**

/a/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	606 (22)	1532 (33)	118 (7)	84 (14)	1.3 (0.7)
IM_m2	595 (16)	1272 (52)	122 (4)	89 (6)	-0.02 (1.5)
IM_m3	662 (22)	1395 (47)	138 (5)	115 (4)	3.7 (0.9)
Mean	**621 (36)**	**1400 (118)**	**126 (10)**	**96 (17)**	**1.7 (1.9)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	630 (33)	1495 (26)	116 (8)	110 (11)	1.2 (0.6)
IM_m2	599 (9)	1293 (54)	120 (3)	108 (9)	-1.8 (2.1)
IM_m3	676 (4)	1443 (14)	141 (5)	151 (8)	1.9 (1.1)
Mean	**635 (38)**	**1410 (95)**	**125 (13)**	**123 (22)**	**0.4 (2.1)**

/o/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	570 (9)	1218 (64)	117 (9)	120 (8)	0.6 (1.9)
IM_m2	497 (5)	1017 (59)	127 (3)	117 (10)	-0.8 (1.1)
IM_m3	554 (14)	1124 (63)	143 (11)	142 (10)	0.6 (2)
Mean	**540 (34)**	**1119 (102)**	**129 (14)**	**126 (15)**	**0.1 (1.7)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	547 (22)	1371 (64)	112 (6)	67 (7)	1.3 (1.2)
IM_m2	510 (11)	1047 (16)	122 (4)	94 (3)	-2.3 (1.1)
IM_m3	558 (16)	1142 (32)	141 (13)	113 (4)	-0.2 (2)
Mean	**538 (26)**	**1187 (147)**	**125 (15)**	**92 (20)**	**-0.4 (2)**

/u/
C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	346 (5)	1558 (48)	123 (6)	55 (6)	3.3 (1.6)
IM_m2	356 (13)	1358 (104)	130 (1)	53 (4)	1.9 (1.9)
IM_m3	375 (10)	1495 (55)	143 (1)	102 (15)	0.5 (1)
Mean	**359 (15)**	**1470 (112)**	**132 (9)**	**70 (25)**	**1.9 (1.8)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
IM_m1	357 (15)	1458 (62)	110 (10)	51 (10)	1 (1.2)
IM_m2	394 (4)	1250 (29)	128 (11)	48 (5)	-0.8 (1.2)
IM_m3	409 (1)	1350 (18)	143 (2)	98 (10)	-1.2 (1.1)
Mean	**387 (24)**	**1352 (96)**	**127 (16)**	**66 (25)**	**-0.3 (1.5)**

C.4 Indonesian vowels by the bilingual Central Javanese/Indonesian speakers

In § C.4.1, I present the values for the Javanese vowels in CVCV words and in § C.4.2, the values for vowels in CVCVC words

C.4.1 Indonesian vowels in CVCV words

/i/
C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	353 (8)	2338 (35)	87 (2)	93 (11)	-0.7 (1.5)
CJ_m2	304 (7)	2137 (42)	140 (2)	90 (12)	-1.4 (1)
CJ_m3	315 (12)	2176 (35)	113 (6)	98 (9)	2.8 (1.2)
Mean	**324 (24)**	**2217 (97)**	**113 (23)**	**93 (10)**	**0.2 (2.2)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	353 (13)	2359 (22)	92 (2)	120 (17)	0.1 (1.7)
CJ_m2	300 (10)	2127 (56)	144 (4)	112 (8)	-3.1 (0.7)
CJ_m3	314 (8)	2188 (40)	112 (5)	116 (8)	3.4 (1.2)
Mean	**323 (25)**	**2224 (109)**	**116 (23)**	**116 (11)**	**0.1 (2.9)**

/e/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	402 (16)	2173 (69)	90 (6)	98 (10)	0.9 (0.3)
CJ_m2	424 (2)	1966 (24)	139 (1)	111 (8)	-2.4 (1.5)
CJ_m3	429 (24)	1888 (63)	113 (4)	113 (5)	0.9 (2.3)
Mean	**418 (19)**	**2009 (135)**	**114 (22)**	**108 (10)**	**-0.2 (2.2)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	396 (15)	2158 (96)	110 (9)	124 (4)	-1.3 (1.9)
CJ_m2	421 (5)	1921 (38)	144 (3)	115 (9)	-4 (1.3)
CJ_m3	411 (17)	1888 (64)	113 (4)	113 (8)	1.7 (2.3)
Mean	**409 (16)**	**1989 (140)**	**122 (17)**	**118 (8)**	**-1.2 (2.9)**

/a/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	729 (81)	1494 (6)	93 (3)	123 (5)	3.4 (0.9)
CJ_m2	679 (22)	1375 (37)	134 (3)	119 (7)	-1.5 (1.3)
CJ_m3	612 (18)	1358 (27)	113 (3)	117 (6)	1.5 (1.1)
Mean	**673 (67)**	**1409 (67)**	**113 (18)**	**120 (6)**	**1.1 (2.4)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	699 (25)	1494 (12)	106 (6)	169 (7)	-0.02 (0.7)
CJ_m2	645 (29)	1383 (45)	146 (4)	144 (6)	3.2 (0.8)
CJ_m3	615 (10)	1362 (9)	110 (2)	145 (11)	3.1 (1.1)
Mean	**653 (42)**	**1413 (65)**	**121 (19)**	**153 (14)**	**-0.04 (2.8)**

/o/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	404 (9)	1162 (60)	99 (5)	100 (7)	1.9 (1)
CJ_m2	409 (15)	1108 (25)	139 (4)	109 (7)	-3.4 (0.9)
CJ_m3	431 (11)	1136 (83)	113 (4)	117 (14)	2.3 (0.9)
Mean	**415 (16)**	**1135 (60)**	**117 (18)**	**109 (12)**	**0.3 (2.9)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	391 (13)	1059 (14)	123 (7)	131 (12)	-0.2 (1.2)
CJ_m2	404 (14)	1066 (24)	143 (3)	130 (19)	-4.4 (1.1)
CJ_m3	423 (9)	1125 (37)	113 (5)	117 (10)	3.2 (1.6)
Mean	**406 (18)**	**1084 (25)**	**126 (14)**	**126 (15)**	**-0.4 (3.4)**

/u/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	339 (16)	1187 (86)	96 (5)	84 (4)	1.5 (0.6)
CJ_m2	322 (23)	1228 (25)	137 (4)	100 (4)	-0.1 (2.3)
CJ_m3	362 (30)	1174 (20)	115 (3)	105 (6)	-2.1 (0.2)
Mean	**341** (27)	**1196** (69)	**116 (18)**	**96 (11)**	**-0.2 (1.9)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	347 (10)	1133 (101)	117 (9)	102 (21)	-2.4 (1.5)
CJ_m2	306 (15)	994 (86)	145 (6)	129 (8)	-2 (2.9)
CJ_m3	361 (14)	1266 (61)	113 (2)	117 (2)	-1.4 (0.5)
Mean	**338** (27)	**1131** (143)	**125 (16)**	**116 (17)**	**-1.9 (1.8)**

C.4.2 Indonesian vowels in CVCVC words

/i/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	336 (15)	2299 (30)	86 (6)	71 (16)	2.3 (1)
CJ_m2	304 (4)	2107 (32)	141 (5)	77 (2)	-2.9 (1.4)
CJ_m3	292 (14)	2167 (62)	113 (7)	84 (6)	3.5 (1.6)
Mean	**310** (22)	**2191** (93)	**113 (24)**	**77 (11)**	**0.9 (3.1)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	414 (14)	2056 (44)	93 (9)	70 (10)	-2.5 (1.7)
CJ_m2	411 (9)	1963 (7)	150 (6)	65 (5)	-4 (0.8)
CJ_m3	414 (24)	1913 (56)	115 (6)	63 (8)	1.2 (1.2)
Mean	**413** (15)	**1977** (72)	**119 (25)**	**66 (8)**	**-1.8 (2.6)**

/e/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	561 (37)	1840 (87)	90 (4)	109 (7)	1.9 (0.7)
CJ_m2	564 (9)	1759 (24)	133 (6)	110 (8)	-2.7 (1)
CJ_m3	558 (1)	1543 (19)	111 (1)	110 (2)	2.4 (2.9)
Mean	**561** (20)	**1714** (139)	**111 (19)**	**109 (6)**	**0.6 (2.9)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	586 (14)	1680 (14)	108 (12)	72 (6)	-0.9 (0.4)
CJ_m2	596 (2)	1612 (22)	145 (3)	80 (4)	-5.3 (1.1)
CJ_m3	560 (13)	1536 (21)	112 (3)	86 (10)	2.5 (2.1)
Mean	**581** (18)	**1610** (64)	**122 (18)**	**79 (9)**	**-1.2 (3.5)**

/a/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	749 (42)	1507 (11)	91 (3)	118 (4)	3.4 (1.9)
CJ_m2	635 (29)	1417 (47)	134 (4)	99 (6)	-2.8 (1)
CJ_m3	614 (19)	1326 (41)	112 (5)	114 (6)	1.5 (1.7)
Mean	**666 (68)**	**1417 (84)**	**112 (19)**	**111 (10)**	**0.7 (3.1)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	667 (31)	1517 (11)	104 (6)	97 (3)	-1 (1.4)
CJ_m2	653 (22)	1477 (26)	149 (3)	97 (4)	-6.2 (1.6)
CJ_m3	621 (30)	1343 (11)	114 (3)	117 (7)	0.6 (1.6)
Mean	**647** (32)	**1445** (79)	**122 (21)**	**103 (11)**	**-2.2 (3.4)**

/o/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	508 (18)	1197 (127)	100 (6)	116 (7)	1.8 (0.9)
CJ_m2	546 (5)	1124 (43)	139 (1)	121 (9)	-2.3 (1.2)
CJ_m3	566 (7)	1068 (54)	114 (2)	129 (9)	-1.1 (2.7)
Mean	**540 (27)**	**1130 (94)**	**117 (17)**	**122 (10)**	**-0.5 (2.4)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	563 (42)	1339 (90)	122 (10)	76 (6)	-0.9 (1.4)
CJ_m2	592 (12)	1139 (37)	148 (2)	91 (2)	-4.3 (1.7)
CJ_m3	551 (6)	1101 (10)	112 (2)	85 (10)	-0.9 (2.6)
Mean	**569** (29)	**1193** (120)	**127 (17)**	**84 (9)**	**-2.1 (2.5)**

/u/
C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	342 (21)	1348 (107)	96 (5)	84 (4)	1.5 (1.7)
CJ_m2	308 (21)	1153 (34)	137 (4)	100 (4)	-0.5 (1.2)
CJ_m3	362 (22)	1131 (58)	115 (3)	105 (6)	-2.5 (0.9)
Mean	**337** (30)	**1210** (72)	**116 (18)**	**89 (16)**	**-0.5 (2.1)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
CJ_m1	405 (15)	1324 (86)	117 (8)	61 (4)	-2.9 (1.1)
CJ_m2	404 (23)	1178 (35)	146 (1)	77 (3)	-4.6 (1.1)
CJ_m3	402 (6)	1220 (25)	115 (4)	66 (5)	-2.9 (1.1)
Mean	**404** (15)	**1241** (81)	**126 (16)**	**68 (8)**	**3.5 (1.3)**

C.5 Indonesian vowels by the bilingual Eastern Javanese/Indonesian speakers

In § C.5.1, I present the values for the Javanese vowels in CVCV words and in § C.5.2, the values for vowels in CVCVC words.

C.5.1 Indonesian vowels in CVCV words

/i/
C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	369 (8)	2112 (51)	129 (1)	74 (10)	4.8 (0.6)
EJ_m2	382 (43)	2052 (90)	139 (2)	72 (12)	-3.7 (1.1)
EJ_m3	331 (7)	1949 (33)	113 (2)	83 (4)	2.5 (1.1)
Mean	**361** (32)	**2038** (90)	**127 (11)**	**77 (10)**	**1.2 (3.9)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	325 (19)	2083 (33)	127 (1)	69 (8)	5.9 (0.7)
EJ_m2	353 (26)	2042 (49)	157 (3)	73 (10)	-6.4 (1.3)
EJ_m3	345 (5)	1920 (27)	114 (2)	90 (8)	0.8 (0.2)
Mean	**341** (21)	**2015** (80)	**133 (19)**	**77 (12)**	**0.1 (5.3)**

/e/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	395 (3)	1984 (102)	127 (1)	85 (8)	1 (1.8)
EJ_m2	420 (17)	2044 (69)	139 (3)	87 (3)	-4.5 (0.3)
EJ_m3	428 (19)	1856 (18)	112 (3)	96 (8)	-2.7 (1.2)
Mean	**414** (20)	**1961** (104)	**126 (11)**	**90 (8)**	**-2.1 (2.7)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff(sd)
EJ_m1	391 (12)	2028 (46)	128 (1)	86 (15)	2.1 (1.8)
EJ_m2	403 (17)	1987 (77)	162 (4)	76 (6)	-7.5 (1)
EJ_m3	443 (9)	1768 (33)	114 (2)	101 (1)	-2.6 (1.2)
Mean	**412** (26)	**1927** (129)	**135 (21)**	**88 (14)**	**-2.7 (4.3)**

/a/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	646 (4)	1572 (46)	124 (2)	89 (10)	1.5 (2.1)
EJ_m2	884 (45)	1457 (52)	141 (5)	97 (13)	0.5 (1.1)
EJ_m3	526 (13)	1404 (35)	108 (1)	113 (9)	-0.5 (0.9)
Mean	**685** (157)	**1477** (84)	**124 (14)**	**99 (14)**	**0.5 (1.6)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff(sd)
EJ_m1	615 (19)	1560 (25)	125 (1)	103 (13)	0.9 (1.5)
EJ_m2	633 (56)	1517 (34)	161 (5)	87 (12)	-2.3 (2)
EJ_m3	537 (6)	1344 (48)	108 (2)	114 (17)	-1.5 (0.9)
Mean	**595** (53)	**1474** (103)	**131 (23)**	**101 (17)**	**-0.9 (1.9)**

/o/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	414 (16)	1500 (70)	127 (2)	86 (8)	2.4 (1.5)
EJ_m2	398 (8)	1125 (32)	141 (4)	92 (5)	-4 (1.2)
EJ_m3	421 (20)	1364 (172)	113 (3)	117 (7)	-0.7 (0.5)
Mean	411 (17)	1330 (190)	**127 (12)**	**98 (16)**	**-0.8 (2.9)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	424 (18)	1479 (86)	129 (2)	81 (10)	3.5 (1.8)
EJ_m2	444 (28)	1355 (108)	163 (5)	84 (6)	-8.1 (1.7)
EJ_m3	426 (16)	1358 (55)	114 (3)	109 (9)	-2.1 (0.9)
Mean	**431** (21)	**1397** (94)	**135 (22)**	**91 (15)**	**-2.2 (5.1)**

/u/

C_CV#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	371 (26)	1637 (10)	126 (3)	79 (9)	2.1 (1)
EJ_m2	383 (34)	1521 (32)	145 (6)	67 (8)	-3.1 (1.6)
EJ_m3	393 (14)	1634 (52)	112 (1)	84 (5)	0.4 (1.7)
Mean	**382** (25)	**1597** (65)	**128 (15)**	**77 (10)**	**-0.2 (2.6)**

CVC_#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	356 (17)	1490 (24)	125 (1)	91 (13)	3.2 (1.9)
EJ_m2	329 (33)	1482 (20)	163 (10)	65 (8)	-7.9 (1.4)
EJ_m3	386 (8)	1598 (3)	112 (1)	88 (11)	-1.3 (1.7)
Mean	**357** (31)	**1524** (53)	**134 (22)**	**81 (16)**	**-2 (5)**

C.5.2 Indonesian vowels in CVCVC words

/i/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff(sd)
EJ_m1	381 (5)	2080 (15)	128 (1)	68 (10)	2.2 (1.1)
EJ_m2	408 (18)	1995 (56)	139 (4)	77 (11)	-3.8 (2.4)
EJ_m3	362 (25)	1880 (32)	112 (2)	80 (5)	2.6 (1.1)
Mean	**384** (26)	**1985** (92)	**126 (12)**	**75 (10)**	**0.3 (3.4)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	393 (13)	1990 (30)	130 (2)	38 (8)	2.7 (1.2)
EJ_m2	428 (17)	1982 (41)	162 (8)	48 (5)	-8.8 (1.2)
EJ_m3	438 (8)	1744 (25)	116 (2)	45 (6)	-2 (0.8)
Mean	**420** (23)	**1905** (123)	**136 (21)**	**43 (7)**	**-2.7 (5)**

/e/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	534 (11)	1781 (47)	127 (1)	82 (7)	2.5 (0.7)
EJ_m2	517 (25)	1800 (71)	143 (8)	82 (2)	-0.8 (1.2)
EJ_m3	528 (14)	1641 (18)	107 (2)	100 (11)	-2.4 (0.2)
Mean	**526** (17)	**1741** (87)	**126 (16)**	**88 (11)**	**-0.2 (2.3)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	534 (17)	1708 (21)	126 (1)	62 (6)	1.5 (1.1)
EJ_m2	542 (20)	1722 (46)	160 (11)	55 (10)	-6.1 (1.3)
EJ_m3	519 (17)	1591 (30)	110 (3)	64 (12)	-4.7 (0.7)
Mean	**532** (19)	**1674** (69)	**132 (23)**	**60 (10)**	**-3.1 (3.6)**

/a/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	652 (21)	1537 (18)	127 (2)	88 (9)	0.8 (1.4)
EJ_m2	787 (52)	1424 (44)	140 (6)	93 (13)	-2.2 (1.3)
EJ_m3	540 (6)	1372 (54)	108 (2)	107 (10)	-1.8 (1.4)
Mean	**660** (110)	**1444** (81)	**125 (14)**	**96 (13)**	**-1.1 (1.9)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	652 (15)	1595 (21)	128 (1)	78 (14)	-0.9 (0.7)
EJ_m2	587 (44)	1295 (106)	156 (8)	82 (5)	-7 (1.5)
EJ_m3	536 (7)	1333 (19)	111 (1)	102 (7)	-4.2 (1.4)
Mean	**592** (55)	**1407** (126)	**131 (20)**	**88 (14)**	**-4 (2.9)**

/o/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	558 (13)	1339 (118)	127 (1)	85 (11)	1.8 (1.4)
EJ_m2	502 (27)	1111 (98)	138 (5)	120 (9)	-2.4 (2.5)
EJ_m3	533 (9)	1163 (70)	110 (3)	122 (10)	-4 (1.2)
Mean	**531** (29)	**1204** (135)	**125 (12)**	**109 (20)**	**-1.5 (3)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	536 (32)	1367 (18)	126 (2)	69 (6)	1.3 (1.3)
EJ_m2	582 (19)	1117 (43)	156 (5)	71 (5)	-7.2 (2.2)
EJ_m3	515 (10)	1224 (41)	108 (5)	83 (11)	-5.6 (0.7)
Mean	**544** (36)	**1236** (198)	**130 (21)**	**74 (9)**	**-3.8 (4.1)**

/u/

C_CVC#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	372 (18)	1685 (53)	124 (1)	76 (7)	2.4 (0.9)
EJ_m2	397 (37)	1483 (64)	140 (4)	72 (3)	-2.8 (1.9)
EJ_m3	363 (14)	1664 (17)	110 (2)	64 (10)	0.8 (0.8)
Mean	**377** (27)	**1611** (105)	**125 (13)**	**71 (8)**	**0.1 (2.6)**

CVC_C#

Speaker	F1 (sd)	F2 (sd)	F0 (sd)	Dur (sd)	Amp diff (sd)
EJ_m1	358 (26)	1671 (47)	125 (3)	44 (9)	4 (0.8)
EJ_m2	449 (29)	1479 (40)	165 (4)	48 (4)	-8.3 (1.6)
EJ_m3	434 (8)	1542 (43)	116 (5)	48 (5)	-3.2 (0.8)
Mean	**414** (47)	**1564** (92)	**135 (22)**	**47 (6)**	**-2.5 (5.4)**

APPENDIX D: ACOUSTIC VALUES FOR THE STOP VOICE QUALITY STUDY

In this appendix, I present the acoustic values for Javanese vowels following breathy vs. clear stops and the acoustic values for Indonesian vowels following voiced vs. voiceless stops. The values for Indonesian vowels as produced by the monolingual speakers are presented in § D.1. The values for Javanese vowels as produced by the Central Javanese speakers are displayed in § D.2, and the values for Indonesian vowels as produced by the bilingual Javanese/Indonesian speakers in § D.3. In each section, the order of presentation is the following: (1) Fundamental frequency, (2) Spectral tilt ((H1-H2) and (H1-A3)), (3) Bandwidth of first formant (H1-A1), and (4) Harmonics-to-noise ratio (HNR).

D.1 Indonesian vowels, by the monolingual speakers

There are four types of vowels in each acoustic measure. These vowels are those following an intervocalic voiceless stop (CVT_), those following an intervocalic voiced stop (CVD_), those following a sequence of a homorganic nasal and a voiceless stop (CVNT_), and those following a sequence of a homorganic nasal and a voiced stop (CVND_). For each vowel type, there are three points of measurements: 30%, 50%, and 70% points in the vowel. For the HNR measure, each vowel type is presented with three frequency ranges: 2-3 kHz, 3-4 kHz, and 4-5 kHz. Each value is followed by a standard deviation value.

(1) Fundamental frequency

CVT_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	206 (7)	174 (9)	214 (9)
50% (sd)	205 (7)	175 (6)	211 (10)
70% (sd)	204 (8)	174 (4)	214 (10)

CVD_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	202 (11)	168 (7)	210 (7)
50% (sd)	197 (10)	166 (7)	211 (6)
70% (sd)	195 (10)	165 (6)	213 (6)

CVNT_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	194 (6)	179 (6)	212 (11)
50% (sd)	192 (5)	178 (6)	209 (9)
70% (sd)	193 (5)	177 (7)	211 (9)

CVND_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	197 (7)	168 (7)	208 (7)
50% (sd)	194 (8)	165 (6)	208 (7)
70% (sd)	195 (8)	165 (6)	210 (8)

(2) Spectral tilt

i. H1-H2

CVT_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	5.6 (2.7)	4.7 (1.5)	7.2 (1.5)
50% (sd)	6.1 (2.9)	6.3 (2.2)	7.9 (1.7)
70% (sd)	7 (4)	7.5 (3.3)	10.6 (2.2)

CVD_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	6.2 (2.9)	4.4 (2)	8.6 (3.3)
50% (sd)	5.4 (2.4)	4.7 (2.2)	9.6 (3)
70% (sd)	6 (2.9)	6.5 (3.8)	11.6 (2.4)

CVNT_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	6.4 (1.1)	3.6 (1.1)	7.5 (2.1)
50% (sd)	6.7 (1.5)	4.8 (2.5)	8.6 (2.5)
70% (sd)	7.4 (2.4)	6.7 (4.1)	10.4 (3.9)

CVND_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	5.6 (1.4)	3.7 (1.4)	9 (2.6)
50% (sd)	6 (1.5)	4.7 (1.4)	9.7 (2.8)
70% (sd)	7.6 (2.4)	6.5 (3.1)	11.2 (2.3)

ii. H1-A3

CVT_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	12.6 (2.9)	14.7 (2.3)	24.8 (3.9)
50% (sd)	13.3 (1.4)	14.8 (4.5)	24.7 (3.8)
70% (sd)	17.3 (5.3)	17.9 (5.8)	29.7 (5.5)

CVD_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	12.7 (2.1)	13.1 (3.6)	27.8 (2.3)
50% (sd)	14.6 (2.5)	13.7 (3.1)	29 (3.5)
70% (sd)	16.1 (3.1)	18.6 (5.4)	31.1 (3.7)

CVNT_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	17 (3.7)	12.7 (3.7)	23.1 (3.5)
50% (sd)	18.8 (3.2)	14.4 (4.3)	24.2 (3.9)
70% (sd)	20.3 (4)	17.2 (7.1)	26 (4.2)

CVND_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	18.1 (2.4)	18.7 (4.7)	30.9 (3.8)
50% (sd)	17.9 (3.2)	20.2 (5.6)	31.4 (3.4)
70% (sd)	20.3 (4)	20.5 (5.1)	33.1 (5.3)

(3) Bandwidth of first formant (H1-A1)

CVT_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	-21 (0.8)	-10.5 (2.5)	-16 (3)
50% (sd)	-19.8 (1)	-9.7 (1.9)	-14.9 (3.7)
70% (sd)	-16.9 (2.9)	-8.4 (1.7)	-12.6 (3.2)

CVD_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	-15.6 (2.1)	-3.1 (1.8)	-10.5 (2.2)
50% (sd)	-16.1 (2.7)	-4 (1.4)	-10.8 (1.9)
70% (sd)	-15.1 (3.3)	-3.2 (2.7)	-9 (2.7)

CVNT_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	-18.7 (2)	-12.9 (1.8)	-14.2 (4.8)
50% (sd)	-18 (1.7)	-12.1 (2.5)	-12.9 (5.1)
70% (sd)	-15.3 (3)	-9.8 (4.1)	-10.3 (6.6)

CVND_

Point in the vowel	Speaker		
	IM_f6	IM_m7	IM_f7
30% (sd)	-11.9 (1.6)	-2.4 (3.2)	-10.5 (2.9)
50% (sd)	-12.4 (1.3)	-3.7 (2.1)	-10.6 (3.3)
70% (sd)	-10.7 (1.6)	-4.2 (2.7)	-8.6 (3.7)

(4) Harmonics-to-noise ratio (HNR)

CVT_

Frequency range	Speaker		
	IM_f6	IM_m7	IM_f7
2-3 kHz (sd)	17.6 (2.1)	14.1 (4.4)	11.6 (4.1)
3-4 kHz (sd)	13.1 (3.1)	10.2 (3.3)	9.3 (3.4)
4-5 kHz (sd)	9.8 (3.5)	7.1 (2.1)	7.4 (3.1)

CVD_

Frequency range	Speaker		
	IM_f6	IM_m7	IM_f7
2-3 kHz (sd)	20.1 (2.6)	17.7 (2.3)	14.4 (2.4)
3-4 kHz (sd)	13.1 (3.7)	13.8 (3.1)	8.5 (2.1)
4-5 kHz (sd)	10.7 (3.4)	9.4 (2.6)	5.8 (2.1)

CVNT_

Frequency range	Speaker		
	IM_f6	IM_m7	IM_f7
2-3 kHz (sd)	15.8 (4)	13.1 (3)	11.9 (3.1)
3-4 kHz (sd)	8.3 (1.6)	10.4 (3.5)	8.4 (2)
4-5 kHz (sd)	6.9 (1.2)	7.7 (2.8)	6.1 (1.9)

CVND_

Frequency range	Speaker		
	IM_f6	IM_m7	IM_f7
2-3 kHz (sd)	17.5 (2.1)	16.1 (2.8)	12.7 (2.6)
3-4 kHz (sd)	11.5 (2)	11 (3.3)	8.3 (2.3)
4-5 kHz (sd)	9 (2.8)	7.4 (2.9)	6 (1.1)

D.2 Javanese vowels, by the Central Javanese speakers

As in the previous section, there are four types of vowels. They are vowels following an intervocalic clear stop (CVT_), those following an intervocalic breathy stop (CVt_), those following a sequence of a homorganic nasal and a clear stop (CVNT_), and those following a sequence of a homorganic nasal and a breathy stop (CVNt_). For each vowel type, there are three points of measurements: 30%, 50%, and 70% points in the vowel. For the HNR measure, each vowel type is presented with three frequency ranges: 2-3 kHz, 3-4 kHz, and 4-5 kHz. Each value is followed by a standard deviation value.

(1) Fundamental frequency

CVT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	156 (8)	89 (6)	108 (3)
50% (sd)	152 (9)	87 (7)	105 (3)
70% (sd)	151 (8)	86 (7)	104 (3)

CVt_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	150 (7)	90 (4)	111 (5)
50% (sd)	143 (5)	88 (5)	107 (4)
70% (sd)	140 (4)	86 (5)	105 (4)

CVNT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	156 (9)	95 (4)	109 (6)
50% (sd)	154 (10)	93 (5)	108 (6)
70% (sd)	154 (11)	93 (5)	106 (5)

CVNt_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	142 (10)	89 (6)	102 (3)
50% (sd)	140 (10)	87 (7)	101 (3)
70% (sd)	139 (10)	86 (8)	100 (3)

(2) Spectral tilt

i. H1-H2

CVT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	1.1 (1.6)	2.4 (1.3)	-8.7 (1.9)
50% (sd)	0.7 (2.1)	2.9 (1.4)	-8.8 (1.4)
70% (sd)	1.3 (1.7)	3.6 (1.4)	-8.5 (1.1)

CVt_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	0.2 (1.2)	6.3 (1.4)	-7.7 (3)
50% (sd)	-0.3 (1.4)	5.1 (1.3)	-7.6 (2.8)
70% (sd)	-0.4 (1.5)	5.1 (1.6)	-7.6 (3.4)

CVNT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	0.7 (1.7)	1.9 (1.2)	-9.6 (1.2)
50% (sd)	0.5 (2.1)	2.5 (1.4)	-9.5 (0.8)
70% (sd)	0.7 (2.3)	3 (1.8)	-9.2 (1.5)

CVNt_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	-0.7 (1.2)	5.9 (2.9)	-6.7 (1.5)
50% (sd)	-1.1 (1.1)	4.5 (2.4)	-6.1 (1.6)
70% (sd)	-1.4 (1.2)	3.6 (2.5)	-5.5 (1.8)

ii. H1-A3

CVT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	29.3 (4.2)	9.9 (2.7)	9.5 (5.1)
50% (sd)	28.5 (4.1)	9.9 (2.9)	9.4 (4.5)
70% (sd)	30 (4.4)	10.5 (3.2)	9.4 (5.3)

CVt_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	33.9 (3.4)	7.4 (2.7)	15.5 (6.3)
50% (sd)	34.2 (3)	9.6 (2.8)	15.1 (6)
70% (sd)	35.2 (4.3)	11.5 (4.1)	17.6 (2.6)

CVNT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	30.3 (3.7)	7.4 (5.9)	7 (4.3)
50% (sd)	29.7 (3.8)	8.4 (6.5)	6.6 (3.2)
70% (sd)	31.6 (4.1)	9.2 (5.4)	8.4 (2.9)

CVNt_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	32.3 (3.6)	9.7 (3.1)	13.9 (4.5)
50% (sd)	32.4 (4.5)	10.1 (4.8)	14.3 (1.8)
70% (sd)	32.6 (4.2)	11.5 (3.6)	15.7 (3.3)

(3) Bandwidth of first formant (H1-A1)

CVT_

Point in the	Speaker		
vowel	CJ_f7	CJ_m6	CJ_m7
30% (sd)	-5.9 (3.1)	-11.4 (2.2)	-14.1 (3.4)
50% (sd)	-5.7 (2.7)	-11.8 (2.1)	-14.1 (2.8)
70% (sd)	-3.9 (2.6)	-10.8 (1.6)	-12.5 (2.5)

CVt_

Point in the	Speaker		
vowel	CJ_f7	CJ_m6	CJ_m7
30% (sd)	7.3 (1.3)	-8.1 (1.4)	-9 (2.5)
50% (sd)	7.2 (1.4)	-7.2 (3.5)	-9.2 (3.2)
70% (sd)	8.4 (2.6)	-6.6 (3.5)	-8.8 (1.7)

CVNT_

Point in the	Speaker		
vowel	CJ_f7	CJ_m6	CJ_m7
30% (sd)	5.5 (1.8)	-7.6 (1.4)	-8.7 (3.8)
50% (sd)	4.1 (2.7)	-8.4 (2.5)	-9 (2.4)
70% (sd)	4.7 (2.1)	-9.5 (2.9)	-9.7 (2.6)

CVNt_

Point in the	Speaker		
vowel	CJ_f7	CJ_m6	CJ_m7
30% (sd)	5.5 (1.8)	-7.6 (1.4)	-8.7 (3.8)
50% (sd)	4.1 (2.7)	-8.4 (2.5)	-9 (2.4)
70% (sd)	4.7 (2.1)	-9.5 (2.9)	-9.7 (2.6)

(4) Harmonics-to-noise ratio (HNR)

CVT_

Frequency range	Speaker		
	CJ_f7	CJ_m6	CJ_m7
2-3 kHz (sd)	12 (2.5)	14.4 (5.3)	9.9 (2.7)
3-4 kHz (sd)	8.3 (2.7)	8.4 (3)	5.7 (1.4)
4-5 kHz (sd)	7.5 (1.4)	6.7 (2)	4.4 (1)

CVt_

Frequency range	Speaker		
	CJ_f7	CJ_m6	CJ_m7
2-3 kHz (sd)	8.3 (1.9)	13.6 (2.6)	9.6 (1.1)
3-4 kHz (sd)	6.1 (1.2)	7.4 (2.6)	6 (1)
4-5 kHz (sd)	5.4 (1.4)	6.2 (1)	5.4 (1.8)

CVNT_

Frequency range	Speaker		
	CJ_f7	CJ_m6	CJ_m7
2-3 kHz (sd)	12.9 (1.1)	17 (3)	9.8 (2.9)
3-4 kHz (sd)	8.9 (1.4)	10 (2)	5.7 (1.6)
4-5 kHz (sd)	7.5 (1.5)	7 (1)	4.3 (1)

CVNt_

Frequency range	Speaker		
	CJ_f7	CJ_m6	CJ_m7
2-3 kHz (sd)	10 (1.9)	12.5 (3.6)	10.3 (2.7)
3-4 kHz (sd)	8 (1.4)	6.8 (2)	6.5 (2)
4-5 kHz (sd)	6.7 (1.4)	6.4 (1.1)	4.8 (1)

D.3 Indonesian vowels, by the bilingual Javanese/Indonesian speakers

The four types of vowels in this section are those following an intervocalic voiceless stop (CVT_), those following an intervocalic voiced stop (CV“D”_), those following a sequence of a homorganic nasal and a voiceless stop (CVNT_), and those following a sequence of a homorganic nasal and a voiced stop (CVN“D”_). For each vowel type, there are three points of measurements: 30%, 50%, and 70% points in the vowel. For the HNR measure, each vowel type is presented with three frequency ranges: 2-3 kHz, 3-4 kHz, and 4-5 kHz. Each value is followed by a standard deviation value.

(1) Fundamental frequency

CVT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	163 (15)	93 (10)	103 (6)
50% (sd)	156 (15)	96 (11)	100 (5)
70% (sd)	155 (17)	92 (9)	95 (9)

CV“D”_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	158 (9)	97 (8)	104 (3)
50% (sd)	153 (8)	96 (6)	102 (3)
70% (sd)	151 (8)	95 (6)	100 (3)

CVNT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	173 (13)	94 (9)	110 (10)
50% (sd)	168 (12)	95 (9)	104 (5)
70% (sd)	166 (10)	95 (9)	100 (7)

CVN“D”_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	159 (10)	91 (6)	102 (3)
50% (sd)	156 (10)	91 (6)	100 (3)
70% (sd)	153 (10)	91 (6)	98 (4)

(2) Spectral tilt

(a) H1-H2

CVT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	0.5 (1.5)	5.3 (1.9)	-7.8 (2.1)
50% (sd)	1.7 (2.1)	7.2 (1.4)	-7 (3.7)
70% (sd)	3.6 (4.1)	7 (1.3)	-4.8 (6.3)

CV"D"_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	3.6 (2.4)	7.1 (4.1)	-4.2 (2.6)
50% (sd)	2.6 (2.3)	8.2 (1.5)	-4 (2.3)
70% (sd)	3.1 (2.8)	9.5 (3.1)	-2 (4.8)

CVNT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	3.3 (2.8)	6.1 (1.7)	-6.4 (2.2)
50% (sd)	3.6 (3.2)	5.6 (1.7)	-6.6 (1.4)
70% (sd)	5.2 (4.9)	6.4 (2.1)	-5.2 (2.2)

CVN"D"_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	3.9 (2.9)	7.1 (1.4)	-5.6 (2.1)
50% (sd)	3.7 (3)	6.3 (1.7)	-3.9 (3.4)
70% (sd)	3.7 (2.4)	6.8 (0.9)	-0.9 (7)

(b) H1-A3

CVT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	23.1 (4.8)	12 (6.8)	22.4 (2.8)
50% (sd)	26.5 (5.9)	13.6 (4)	22.8 (4.6)
70% (sd)	27 (5.2)	17 (4)	23.8 (5.2)

CV“D”_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	27.8 (3.6)	10.8 (4)	32.7 (5.6)
50% (sd)	26.3 (2.7)	13.8 (3)	31.9 (4.2)
70% (sd)	28.3 (2.9)	14.3 (2.7)	30.4 (4.3)

CVNT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	33.5 (4.3)	14.1 (3.1)	22.5 (4.3)
50% (sd)	35.4 (4.5)	14.5 (2.3)	22.5 (4.3)
70% (sd)	35.8 (4.6)	15.7 (3.3)	25.3 (4.5)

CVN“D”_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	28.3 (6.2)	15.1 (2.3)	30.8 (4.7)
50% (sd)	30 (5.9)	15.9 (2)	29.8 (5.5)
70% (sd)	32 (4)	16.1 (3.6)	29 (5.4)

(3) Bandwidth of first formant (H1-A1)

CVT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	-15.9 (2.9)	-13.8 (3.2)	-10.9 (1.9)
50% (sd)	-12.8 (5.1)	-13 (3.5)	-10 (3.3)
70% (sd)	-10.3 (5.4)	-11.1 (2.7)	-10.9 (1.4)

CV“D”_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	-4.6 (3.8)	-8.6 (5)	1.1 (3.7)
50% (sd)	-7 (2)	-8.2 (2)	-1 (3)
70% (sd)	-5 (3.9)	-5.3 (2.2)	-0.4 (7)

CVNT_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	-12.6 (5.2)	-14.5 (1.7)	-11.1 (2.8)
50% (sd)	-11.6 (6.5)	-13.4 (2.7)	-11.2 (3.4)
70% (sd)	-9.2 (7.3)	-11.5 (4.2)	-8 (3.6)

CVN“D”_

Point in the vowel	Speaker		
	CJ_f7	CJ_m6	CJ_m7
30% (sd)	-5.4 (4.2)	-5.7 (1.1)	-2.6 (3.2)
50% (sd)	-5.8 (4)	-8 (2)	-3.2 (4)
70% (sd)	-5.3 (2.6)	-7.7 (2)	-0.5 (5.7)

(4) Harmonics-to-noise ratio (HNR)

CVT_

Frequency range	Speaker		
	CJ_f7	CJ_m6	CJ_m7
2-3 kHz (sd)	10 (4.5)	13.4 (5)	6.7 (2.3)
3-4 kHz (sd)	7 (3)	9.3 (4)	4.9 (1.4)
4-5 kHz (sd)	6.5 (2.7)	8 (3.1)	3.8 (1)

CV“D”_

Frequency range	Speaker		
	CJ_f7	CJ_m6	CJ_m7
2-3 kHz (sd)	12.8 (3.4)	14.4 (3)	7.5 (2)
3-4 kHz (sd)	8 (2.7)	8 (3.1)	5.4 (1.5)
4-5 kHz (sd)	5.7 (2)	5.6 (1.7)	4.3 (0.8)

CVNT_

Frequency range	Speaker		
	CJ_f7	CJ_m6	CJ_m7
2-3 kHz (sd)	11.9 (3.6)	11 (2.7)	6.4 (2.7)
3-4 kHz (sd)	8.3 (2.4)	6.7 (2.4)	4.6 (1.6)
4-5 kHz (sd)	7.5 (0.9)	5.6 (1.7)	3.7 (1.4)

CVN“D”_

Frequency range	Speaker		
	CJ_f7	CJ_m6	CJ_m7
2-3 kHz (sd)	13.4 (4.8)	13.2 (3.7)	7.8 (2.9)
3-4 kHz (sd)	7.6 (2.9)	6.4 (2.5)	5.5 (1.3)
4-5 kHz (sd)	5.4 (1.5)	6.9 (3)	4.5 (1)

APPENDIX E: ACOUSTIC VALUES FOR THE NC CLUSTER SYLLABIFICATION STUDY

In this appendix, I present the acoustic measurements for the penultimate vowels preceding an intervocalic root-medial stop (VCV), an intervocalic root-medial nasal (VNV), and a root-medial NC cluster (VNCV), to determine the syllable affiliation of root-medial NC clusters in Javanese and Indonesian (for analyses, see Chapter 5). The values for the Javanese vowels as produced by the Central Javanese speakers are shown in § E.1. The values shown in § E.2 are those for the Indonesian vowels as produced by the monolingual speakers, and those presented in § E.3 are for the Indonesian vowels as produced by the bilingual speakers. In each section, the order of presentation is as follows: (1) Duration of the penultimate vowel; (2) Duration of the intervocalic stop, the intervocalic nasal, and the root-medial NC; (3) H1-A1 values of the penultimate vowel. Each value for the individual speaker represents an averaged value across four repetitions of the recorded tokens.

E.1 Javanese NC clusters and pre-NC vowels

In the tables of the values, T represents clear (or modal) stops, $T^{ɦ}$ represents breathy stops, and N represents nasals.

(1) Durations of the penultimate vowels

	Speaker			
	CJ_f7	CJ_m6	CJ_m7	**Mean**
C_TV (sd)	109 (17)	102 (10)	105 (17)	**105 (15)**
C_T^{ɦ}V (sd)	91 (24)	99 (10)	105 (13)	**99 (17)**
C_NV (sd)	95 (22)	100 (20)	115 (11)	**104 (19)**
C_NTV (sd)	91 (25)	104 (23)	93 (3)	**96 (19)**
C_NT^{ɦ}V (sd)	96 (16)	98 (13)	101 (14)	**98 (14)**

(2) Durations of the intervocalic stops, nasals, and NC clusters

	Speaker			
	CJ_f7	CJ_m6	CJ_m7	**Mean**
CVTV (sd)	111 (18)	108 (16)	71 (10)	**97 (24)**
CVT^{ɦ}V (sd)	106 (23)	120 (14)	126 (27)	**118 (23)**
CVNV (sd)	125 (33)	125 (16)	96 (19)	**116 (27)**
CVNTV (sd)	192 (25)	154 (17)	129 (22)	**158 (33)**
nasal	124 (21)	91 (13)	92 (18)	**102 (23)**
stop	68 (9)	63 (11)	37 (9)	**56 (17)**
CVNT^{ɦ}V (sd)	152 (32)	151 (16)	130 (24)	**145 (26)**
nasal	129 (23)	118 (17)	106 (24)	**118 (22)**
stop	23 (10)	33 (5)	24 (8)	**27 (9)**

(3) H1-A1 values of the penultimate vowels

		Speaker			
		CJ_f7	CJ_m6	CJ_m7	**Mean**
C_TV (sd)	50%	-3.5 (2)	-11 (2)	-13.6 (2)	**-9.4 (5)**
	75%	-2.5 (2)	-5.2 (5)	-9.9 (3)	**-5.9 (5)**
C_T^{ɦ}V (sd)	50%	-0.9 (3)	-9.5 (2)	-13.4 (6)	**-7.9 (7)**
	75%	2.6 (6)	-7.9 (3)	-8.6 (7)	**-4.6 (8)**
C_NV (sd)	50%	-3.4 (2)	-9.3 (3)	-14.4 (2)	**-9 (5)**
	75%	-2.4 (3)	-6.2 (2)	-9.8 (3)	**-6.1 (4)**
C_NTV (sd)	50%	-3.6 (2)	6.3 (3)	-14.8 (1)	**-8.2 (5)**
	75%	-3.5 (3)	-2.4 (3)	-15.5 (3)	**-7.1 (7)**
C_NT^{ɦ}V (sd)	50%	0.6 (3)	-7 (2)	-12.3 (2)	**-6.3 (6)**
	75%	2.8 (6)	-1 (2)	-11.7 (3)	**-3.3 (7)**

E.2 Indonesian NC clusters and pre-NC vowels of the monolingual speakers

In the tables of the values, T represents voiceless stops, D represents voiced stops, and N represents nasals.

(1) Durations of the penultimate vowels

	Speaker			
	IM_f6	IM_m7	IM_f7	**Mean**
C_TV (sd)	60 (7)	75 (6)	75 (7)	**70 (9)**
C_DV (sd)	73 (8)	86 (7)	94 (9)	**84 (12)**
C_NV (sd)	71 (6)	83 (6)	85 (11)	**79 (10)**
C_NTV (sd)	60 (7)	79 (7)	80 (11)	**73 (12)**
C_NDV (sd)	59 (7)	83 (6)	88 (14)	**77 (17)**

(2) Durations of the intervocalic stops, nasals, and NC clusters

	Speaker			
	IM_f6	IM_m7	IM_f7	**Mean**
CVTV (sd)	82 (4)	84 (7)	103 (6)	**90 (11)**
CVDV (sd)	57 (11)	69 (7)	78 (11)	**68 (13)**
CVNV (sd)	61 (9)	65 (4)	84 (11)	**70 (13)**
CVNTV (sd)	117 (8)	113 (7)	126 (17)	**119 (12)**
nasal	71 (8)	63 (7)	64 (11)	**66 (9)**
stop	46 (6)	50 (6)	62 (8)	**53 (9)**
CVNDV (sd)	111 (14)	104 (5)	102 (15)	**106 (12)**
nasal	93 (12)	85 (6)	81 (13)	**86 (11)**
stop	18 (4)	19 (4)	21 (4)	**20 (4)**

(3) H1-A1 values of the penultimate vowels

H1-A1		Speaker			
		IM_f6	IM_m7	IM_f7	**Mean**
C_TV (sd)	50%	-8.5 (4)	-13.2 (3)	-12 (3)	**-11.3 (4)**
	75%	-13.5 (4)	-6.8 (3)	-11.6 (4)	**-10.6 (5)**
C_DV (sd)	50%	-9 (4)	-15.4 (4)	-13.7 (3)	**-12.7 (4)**
	75%	-13 (4)	-4 (4)	-9 (3)	**-8.7 (5)**
C_NV (sd)	50%	-9.6 (2)	-12 (3)	-10.8 (3)	**-10.8 (3)**
	75%	-10.3 (3)	-7.5 (2)	-6.3 (3)	**-8 (3)**
C_NTV (sd)	50%	-9.4 (3)	-12 (2)	-11.1 (3)	**-10.9 (3)**
	75%	-9.6 (2)	-7.8 (9)	-9.1 (4)	**-8.8 (6)**
C_NDV (sd)	50%	-9.7 (3)	-12.2 (3)	-9.2 (3)	**-10.4 (3)**
	75%	-10.5 (3)	-5.5 (2)	-6.3 (3)	**-7.4 (4)**

E.3 Indonesian NC clusters and pre-NC vowels of the bilingual speakers

In the tables of the values, T represents voiceless stops, "D" represents voiced stops acoustically realized as breathy, and N represents nasals.

(1) Durations of the penultimate vowels

Duration	Speaker			
	CJ_f7	CJ_m6	CJ_m7	**Mean**
C_TV (sd)	102 (10)	74 (13)	76 (7)	**84 (17)**
C_"D"V (sd)	102 (9)	94 (25)	68 (6)	**88 (21)**
C_NV (sd)	100 (10)	91 (9)	74 (12)	**88 (15)**
C_NTV (sd)	97 (10)	84 (11)	77 (9)	**86 (13)**
C_N"D"V (sd)	91 (7)	87 (15)	73 (10)	**84 (13)**

(2) Durations of the intervocalic stops, nasals, and NC clusters

Duration	Speaker			
	CJ_f7	CJ_m6	CJ_m7	**Mean**
CVTV (sd)	130 (13)	104 (15)	87 (10)	**107 (22)**
CV"D"V (sd)	142 (22)	132 (21)	105 (16)	**127 (25)**
CVNV (sd)	108 (11)	83 (8)	87 (12)	**93 (15)**
CVNTV (sd)	172 (18)	149 (10)	109 (9)	**143 (29)**
nasal	94 (9)	79 (8)	55 (10)	**76 (19)**
stop	78 (20)	70 (8)	54 (5)	**67 (16)**
CVN"D"V (sd)	151 (11)	138 (13)	120 (10)	**136 (17)**
nasal	123 (12)	107 (9)	90 (14)	**107 (18)**
stop	28 (4)	31 (10)	30 (5)	**30 (7)**

(3) H1-A1 values of the penultimate vowels

H1-A1		Speaker			
		CJ_f7	CJ_m6	CJ_m7	**Mean**
C_TV (sd)	50%	-11.4 (2)	-11.2 (6)	-2.6 (3)	**-8.4 (6)**
	75%	-7.3 (3)	-11.2 (5)	-1.1 (3)	**-6.5 (6)**
C_"D"V (sd)	50%	-7.6 (3)	-17.1 (4)	0.6 (3)	**-8 (8)**
	75%	-2.8 (3)	-12.8 (4)	2 (3)	**-4.5 (7)**
C_NV (sd)	50%	-5.1 (3)	-14.8 (2)	-1.7 (3)	**-6.1 (7)**
	75%	-3.5 (2)	-12.2 (3)	3.6 (3)	**-4 (7)**
C_NTV (sd)	50%	-11.6 (6)	-13.4 (3)	-11.2 (3)	**-12 (4)**
	75%	-3.6 (2)	-11.2 (7)	1.1 (4)	**-4.5 (7)**
C_N"D"V (sd)	50%	-5.8 (4)	-8 (2)	-3.2 (4)	**-5.6 (7)**
	75%	-3 (2)	-11.2 (4)	2.3 (2)	**-4 (6)**

BIBLIOGRAPHY

Adelaar, K. A. (1983). Malay Consonant-Harmony: An Internal Reconstruction. In J. Collins (ed.) *Studies in Malay Dialects*, Part I. Jakarta: Atma Jaya University, 57-69. (NUSA: Linguistic Studies of Indonesian and Other Languages in Indonesia, No. 16)

Adisasmito, N. (1993). Syllable Structure and the Nature of Schwa in Indonesian. *Studies in the Linguistic Sciences* 23, 1-19.

Adisasmito, N. (1998). Faithfulness Constraints and Consonant Patterns in Indonesian. In M. Pearson (ed.) *Recent Papers in Austronesian Linguistics*. Los Angeles, CA: UCLA Department of Linguistics, 1-18. (UCLA Occasional Papers in Linguistics 21)

Adisasmito, N. and A. Cohn. (1996). Phonetic Correlates of Primary and Secondary Stress in Indonesian: A Preliminary Study. *Working Papers of the Cornell Phonetics Laboratory* 11, 1-15.

Adisasmito-Smith, N. (1998). Degemination in Indonesian Phonology and Phonetics. *Working Papers of the Cornell Phonetics Laboratory* 12, 1-26. (Also published in E. Zeitoun and P. Li (eds.) *Selected Papers from the Eighth International Conference on Austronesian Linguistics*, 251-276.)

Adisasmito-Smith, N. (1999a). The Acoustic Characteristics of Javanese Breathy/Clear Phonation Contrast. Paper presented at the 6th Austronesian Formal Linguistics Association, Toronto, Canada.

Adisasmito-Smith, N. (1999b). The Influence of Javanese Vowel Patterning on Indonesian: An Acoustic Investigation. *Proceedings of the 14th International Congress of Phonetic Sciences*, 1109-1112.

Adisasmito-Smith, N. (2003). Medial Nasal + Stop Clusters in Indonesian and Javanese: A Preliminary Acoustic Account. *Cornell Working Papers in Linguistics* 19, 1-19.

Alieva, N., V. Arakin, A. Oglobin, and J. Sirk. (1972). *Grammatika Indonezijskogo Jazyka*. Moscow: Nauka.

Allen, J. S. and J. Miller. (1999). Effects of Syllable-Initial Voicing and Speaking Rate on the Temporal Characteristics of Monosyllabic Words. *Journal of the Acoustical Society of America* 106, 2031-2039.

Anderson, B. (1999). Source-Language Transfer and Vowel Accommodation in the Patterning of Cherokee English /ai/ and /oi/. *American Speech* 74, 339-368.

Archangeli, D. (1998). The Grounding Hypothesis and Javanese Vowels. In S. L. Chelliah and W. J. de Reuse (eds.) *Papers from the Fifth Annual Meeting of the Southeast Asian Linguistics Society 1995*. Tempe, AZ: Program of Southeast Asia studies, Arizona State University, 1-19.

Bakker, P. (1995). Pidgins. In J. Arends, P. Muysken, and N. Smith (eds.) *Pidgins and Creoles, an Introduction*. Philadelphia, PA: John Benjamins Publishing Company, 25-39.

Beddor, P. and H. K. Yavuz. (1995). The Relation between Vowel-to-Vowel Coarticulation and Vowel Harmony in Turkish. *Proceedings of the XIIIth International Congress of Phonetic Sciences* vol. 2, 44-51.

Bell, A. (1984). Language Style as Audience Design. *Language in Society* 13, 145-204.

Bell, A. (1990). Audience and Referee Design in New Zealand Media Language. In A. Bell and J. Holmes (eds.) *New Zealand Ways of Speaking English*. Clevedon, England: Multilingual Matters, 165-194.

Bell-Berti, F. (1985). Control of Pharyngeal Cavity Size for English Voiced and Voiceless Stops. *Journal of the Acoustical Society of America* 57, 456-461.

Bentahila, A. (1983). *Language Attitudes among Arabic-French bilinguals in Morocco*. Clevedon, English: Multilingual Matters.

Benua, L. (1996). Transderivational Identity in Javanese. Handout for a talk presented at the City University of New York.

Bickley, C. (1982). Acoustic Analysis and Perception of Breathy Vowels. *Speech Communication Group Working Papers* 1, 71-82. (Research Laboratory of Electronics, MIT)

Blankenship, B. (1997). *The Time Course of Breathiness and Laryngealization in Vowels*. Ph.D. dissertation, University of California in Los Angeles.

Bloomfield, L. (1933). *Language*. New York: Henry Holt and company.

Bradlow, A. (1993). *Language-Specific and Universal Aspects of Vowel Production and Perception: A Cross-Linguistic Study of Vowel Inventories*. Ph.D. dissertation, Cornell University.

Browman, C. and L. Goldstein. (1986). Towards an Articulatory Phonology. *Phonology Yearbook* 3, 219-252.

Burns, S., P. Matthews, and E. Nolan-Conroy. (2001). In C. Lucas (ed.) *The Sociolinguistics of Sign Languages*. New York: Cambridge University Press, 181-215.

Cao, J. and I. Maddieson. (1992). An Exploration of Phonation Types in Wu Dialects of Chinese. *Journal of Phonetics* 20, 77-92.

Ní Chasaide, A. and C. Gobl. (1997). Voice Source Variation. In W. Hardcastle and J. Laver (eds.) *The Handbook of Phonetic Sciences*. Cambridge, MA: Blackwell, 427-461.

Chen, M. (Matthew) (1970). Vowel Length Variation as a Function of the Voicing of the Consonant Environment. *Phonetica* 22, 129-159.

Chen, M. (Marilyn) (1997). Acoustic Correlates of English and French Nasalized Vowels. *Journal of the Acoustical Society of America* 102, 2360-2370.

Chen, M. (Marilyn) (2000). Acoustic Analysis of Simple Vowels Preceding a Nasal in Standard Chinese. *Journal of Phonetics* 28, 43-67.

Choi, J. and P. Keating. (1991). Vowel-to-Vowel Coarticulation in Three Slavic Languages. *UCLA Working Papers in Phonetics* 78, 78-85.

Chomsky, N. and M. Halle. (1968). *The Sound Pattern of English (SPE)*. New York: Harper and Row.

Clements, G. N. (1985). Akan Vowel Harmony: A Nonlinear Analysis. In D. Goyvaerts (ed.) *African Linguistics: Essays in Memory of M.W.K. Semikenke*. Philadelphia, PA: John Benjamins, 55-98.

Clements, G. N. (1986). Compensatory Lengthening and Consonant Gemination in LuGanda. In L. Wetzels and E. Sezer (eds.) *Studies in Compensatory Lengthening*. Dordrecht: Foris Publications, 37-77.

Clements, G. N. (1990). The Role of the Sonority Cycle in Core Syllabification. In J. Kingston and M. Beckman (eds.) *Between the Grammar and Physics of Speech*. New York: Cambridge University Press, 283-333.

van Coetsem, F. (1988). *Loan Phonology and the Two Transfer Types in Language Contact*. Providence, RI: Foris Publications.

Cohn, A. (1989). Stress in Indonesian and Bracketing Paradoxes. *Natural Language and Linguistic Theory* 7, 167-216.

Cohn, A. (1990). *Phonetic and Phonological Rules of Nasalization*. Ph.D. dissertation, University of California in Los Angeles.

Cohn, A. (1995). Phonetics and Phonology. *Working Papers of the Cornell Phonetics Laboratory* 10, 1-37.

Cohn, A. (1998). The Phonetics-Phonology Interface Revisited; Where's Phonetics? *Texas Linguistic Forum (Exploring the Boundaries between Phonetics and Phonology)* 41, 25-40. (Proceedings of the 1998 Texas Linguistics Society Conference)

Cohn, A. and W. Ham. (1998). Temporal Properties of Madurese Consonants: A Preliminary Report. *Working Papers of the Cornell Phonetics Laboratory* 12, 27-51.

Cohn, A. and K. Lockwood. (1994). A Phonetic Description of Madurese and Its Phonological Implications. *Working Papers of the Cornell Phonetics Laboratory* 9, 67-92.

Cohn, A. and J. McCarthy. (1998). Alignment and Parallelism in Indonesian Phonology. *Working Papers of the Cornell Phonetics Laboratory* 12, 53-137.

Cohn, A., W. Ham, and R. Podesva. (1999). The Phonetic Realization of Singleton-Geminate Contrasts in Three Languages of Indonesia. *Proceedings of the 14th International Congress of Phonetic Sciences*, 587-590.

Coupland, N., A. Williams, and P. Garrett. (1999). "Welshness" and "Englishness" as Attitudinal Dimensions of English Language Varieties in Wales. In D. Preston (ed.) *Handbook of Perceptual Dialectology, Vol. 1*. Philadelphia: John Benjamins Publishing Company, 333-343.

Crystal, T. and A. House. (1988). The Duration of American-English Vowels: An Overview. *Journal of Phonetics* 16, 263-284.

Davis, K. (1994). Stop voicing in Hindi. *Journal of Phonetics* 22, 177-193.

Disner, S. (1983). *Vowel Quality: The Relation between Universal and Language Specific Factors*. Ph.D. dissertation, University of California in Los Angeles.

Djajengwasito, S. (1975). *Javanese Speech Styles: A Multiple Discriminant Analysis of Social Constraints*. Ph.D. dissertation, Cornell University.

Dudas, K. (1976). *The Phonology and Morphology of Modern Javanese*. Ph.D. dissertation, University of Illinois in Urbana-Champaign.

Echols, J. and H. Shadily. (1992). *Kamus Indonesia-Inggris*. Jakarta: Gramedia.

Errington, J. (1981). *Changing Speech Levels among a Traditional Javanese Elite Group*. Ph.D. dissertation, University of Chicago.

Errington, J. (1985). On the Nature of the Sociolinguistic Sign: Describing the Javanese Speech Levels. In E. Mertz and R. Parmentier (eds.) *Semiotic Mediation: Sociocultural and Psychological Perspectives*. Orlando, FL: Academic Press, 287-310.

Fagan, J. (1988). Javanese Intervocalic Stop Phonemes: The Light/Heavy Distinction. In R. McGinn, J. Coady and P. Hubbard (eds.) *Studies in Austronesian Linguistics*. Athens: Center for Southeast Asia Studies, Ohio University Center for International Studies, 173-200.

Farnetani, E. and S. Kori. (1986). Effects of Syllable and Word Structure on Segmental Durations in Spoken Italian. *Speech Communication* 5, 17-34.

Ferguson, C. (1959). Diglossia. *Word* 15, 325-340. (Reprinted in P. Giglioli (ed.) *Language and Social Context*. (1972). New York: Penguin Books Ltd., 232-251.)

Fischer-Jørgensen, E. (1954). Acoustic Analysis of Stop Consonants. *Miscellanea Phonetica* 2: 42-49. (Reprinted in I. Lehiste (ed.) *Readings in acoustic phonetics*. (1954). Cambridge, MA: MIT Press, 137-154.)

Fischer-Jørgensen, E. (1967). Phonetic Analysis of Breathy (Murmured) Vowels in Gujarati. *Indian Linguistics* 28, 71-139.

Flanagan, J. (1957). Estimates of the Maximum Precision Necessary in Quantizing Certain “Dimensions” of Vowel Sounds. *Journal of the Acoustical Society of America* 29, 533-534.

Flanagan, J. and M. Saslow. (1958). Pitch Discrimination of Synthetic Vowels. *Journal of the Acoustical Society of America* 30, 435-442.

Flege, J., C. Schirru, and I. MacKay. (2003). Interaction between the Native and Second Language Phonetic Subsystems. *Speech Communication* 40, 467-491.

Fujimura, O. and J. Lindqvist. (1971). Sweep-Tone Measurements of Vocal-Tract Characteristics. *Journal of the Acoustical Society of America* 49, 541-558.

Gay, T. (1978). Effect of speaking rate on vowel formant movements. *Journal of the Acoustical Society of America* 63, 223-230.

Gil, D. (2002). Ludlings in Malayic Languages: An Introduction. To appear in *PELBBA* 15.

Godinez, M. and I. Maddieson. (1985). Vowel Differences between Chicano and General Californian English. *International Journal of the Sociology of Language* 53, 43-58.

Grimes, B. (ed.) (1996). *Ethnologue*. Dallas, TX: Summer Institute of Linguistics.

Ham, W. (1998). *Phonetic and Phonological Aspects of Geminate Timing*. Ph.D. dissertation, Cornell University.

Hanson, H. (1995). Synthesis of Female Speech Using the Klatt Synthesizer. *Speech Communication Group Working Papers* (MIT) 10, 84-103.

Hanson, H. (1997). Glottal Characteristics of Female Speakers: Acoustic Correlates. *Journal of the Acoustical Society of America* 101, 466-481.

Hargus, S. (1993). Modeling the Phonology-Morphology Interface. In S. Hargus and E. M. Kaisse (eds.) *Studies in Lexical Phonology*. San Diego, CA: Academic Press: 45-74.

‘t Hart, J., R. Collier, and A. Cohen. (1990). *A Perceptual Study of Intonation*. New York: Cambridge University Press.

Hayes, B. and T. Stivers. (in progress). Postnasal Voicing. UCLA manuscript (downloadable file from the first author’s website: http://www.linguistics.ucla.edu/people/hayes/phonet/ ncphonet.pdf).

Hayward, K. (1993). /p/ vs. /b/ in Javanese: Some Preliminary Data. *Working Papers in Linguistics and Phonetics* 3, 1-33.

Hayward, K. (1995). /p/ vs. /b/ in Javanese: the Role of the Vocal Folds. *Working Papers in Linguistics and Phonetics* 5, 1-11.

Hayward, K. and Muljono. (1991). The Dental/Alveolar Contrast in Javanese. *Bulletin of the School of Oriental and African Studies* 54, 126-144.

Hazan, V. and G. Boulakia. (1993). Perception and Production of a Voicing Contrast by French-English Bilinguals. *Language and Speech* 36, 17-38.

Henton, C. (1987). Phonetic Considerations for the Synthesis of Female Voices. *Proceedings of the Eleventh International Congress of Phonetic Sciences* 3, 270-273.

Henton, C. and R. Bladon. (1985). Breathiness in Normal Female Speech: Inefficiency versus Desirability. *Language & Communication* 5, 221-227.

Henton, C., P. Ladefoged, and I. Maddieson. (1992). Stops in the World's Languages. *Phonetica* 49, 65-101.

Herbert, P. and A. Milner. (1989). *South-East Asia: Languages and Literatures, a Select Guide*. Honolulu, HI: University of Hawaii Press.

Herbert, R. (1986). *Language Universals, Markedness Theory and Natural Phonetic Processes*. Berlin: Mouton de Gruyter.

Hillenbrand, J., R. A. Cleveland, and R. L. Erickson. (1994). Acoustic Correlates of Breathy Vocal Quality. *Journal of Speech and Hearing Research* 37, 769-778.

Ho Dac, T. (1997). Tonal Facilitation of Code-Switching. *Australian Review of Applied Linguistics* 20, 129-151.

Hombert, J-M. (1978). Consonant Types, Vowel Quality, and Tone. In V. Fromkin (ed.) *Tone, a Linguistic Survey*. New York: Academic Press, 77-111.

Horne, E. (1974). *Javanese-English Dictionary*. New Haven: Yale University Press.

House, A. and G. Fairbanks. (1953). The Influence of Consonant Environment upon the Secondary Acoustical Characteristics of Vowels. *Journal of the Acoustical Society of America* 25, 105-113.

House, A. and K. Stevens. (1956). Analog Studies of the Nasalization of Vowels. *Journal of the Acoustical Society of America* 21, 218-232.

Hubbard, K. (1995). Toward a Theory of Phonological and Phonetic Timing: Evidence from Bantu. In B. Connell and A. Arvaniti (eds.) *Phonology and Phonetic Evidence*. New York: Cambridge University Press, 168-187. (Papers in Laboratory Phonology IV)

Huffman, M. (1987). Measures of Phonation Type in Hmong. *Journal of the Acoustical Society of America* 81, 495-504.

Jackson, M., P. Ladefoged, M. Huffman, and N. Antoñanzas-Barroso. (1985a). Measures of Spectral Tilt. *UCLA Working Papers in Phonetics* 61, 72-78.

Jackson, M., P. Ladefoged, M. Huffman, and N. Antoñanzas-Barroso. (1985b). Automated Measures of Spectral Tilt. *UCLA Working Papers in Phonetics* 62, 77-88.

Jessen, M. and J.C. Roux. (2002). Voice Quality Differences Associated with Stops and Clicks in Xhosa. *Journal of Phonetics* 30, 1-52.

Jones, R. (1984). Loan Words in Contemporary Indonesian. In J. Verhaar (ed.) *Towards a Description of Contemporary Indonesian: Preliminary Studies, Part II*. Jakarta: Universitas Katolik Indonesia Atma Jaya, 1-38. (NUSA, Linguistic Studies of Indonesian and Other Languages in Indonesian, Vol. 19)

Karlsson, I. (1994). Acoustic Description of Consonants in Female Speech: Voiced Consonants. *Working Papers* (Lund, Sweden) 43, 80-83.

Kartomihardjo, S. (1971). *Speech Levels as Indicators of Social Classes in Javanese Novels (A Preliminary Investigation)*. M.A. thesis, Cornell University.

Keating, P. (1985). Universal Phonetics and the Organization of Grammars. In V. Fromkin (ed.) *Phonetic Linguistics: Essays in Honor of Peter Ladefoged*. Orlando, FL: Academic Press, 115-132.

Keating, P. (1996). The Phonology-Phonetics Interface. *UCLA Working Papers in Phonetics* 92, 45-60.

Kessinger, R. and S. Blumstein. (1998). Effects of Speaking Rate on Voice-Onset Time and Vowel Production: Some Implications for Perception Studies. *Journal of Phonetics* 26, 117-128.

Khattab, G. (2000). VOT Production in English and Arabic Bilingual and Monolingual Children. *Leeds Working Papers in Linguistics and Phonetics* 8, 95-122.

Kingston, J. and R. Diehl. (1994). Phonetic Knowledge. *Language* 70, 419-454.

Kirk, P. L., P. Ladefoged, and J. Ladefoged. (1984). Using a Spectrograph for Measures of Phonation Types in a Natural Language. *UCLA Working Papers in Phonetics* 59, 102-113.

Klatt, D. and L. Klatt. (1990). Analysis, Synthesis, and Perception of Voice Quality Variations among Female and Male Talkers. *Journal of the Acoustical Society of America* 87, 820-857.

de Krom, G. (1993). A Cepstrum-Based Technique for Determining a Harmonics-to-Noise Ratio in Speech Signals. *Journal of Speech and Hearing Research* 36, 254-266.

Ladefoged, P. (1971). *Preliminaries to Linguistic Phonetics*. Chicago: University of Chicago Press.

Ladefoged, P. (1973). The Feature of the Larynx. *Journal of Phonetics* 1, 73-83.

Ladefoged, P. (1983). The Linguistic Use of Different Phonation Types. In D. Bless and J. Abbs (eds.) *Vocal Fold Physiology: Contemporary Research and Clinical Issues*. San Diego, CA: College Hill Press, 351-360.

Ladefoged, P. (2001). *A Course in Phonetics*. Boston, MA: Heinle & Heinle.

Ladefoged, P. and N. Antoñanzas-Barroso. (1985). Computer Measures of Breathy Voice Quality. *UCLA Working Papers in Phonetics* 61, 79-86.

Ladefoged, P. and I. Maddieson. (1986). (Some of) the Sounds of the World's Languages. *UCLA Working Papers in Phonetics* 64.

Ladefoged, P., I. Maddieson, and M. Jackson. (1988). Investigating Phonation Types in Different Languages. In O. Fujimura (ed.) *Vocal Physiology: Voice Production Mechanisms and Functions*. New York: Raven Press, 297-317.

Laksman, M. (1994). Location of Stress in Indonesian Words and Sentences. In C. Odé and V. van Heuven (eds.) *Experimental Studies of Indonesian Prosody*. Leiden: Valkgroep Talen en Culturen van Zuidoost-Azië en Oceanië. (SEMAIAN 9)

Lapoliwa, H. (1981). *A Generative Approach to the Phonology of Bahasa Indonesia*. Canberra: Department of Linguistics, Research School of Pacific and Asian Studies, The Australian National University. (Pacific Linguistics, Series D, No. 34)

Laver, J. (1980). *The Phonetic Description of Voice Quality*. New York: Cambridge University Press.

Laver, J. (1994). *Principles of Phonetics*. New York: Cambridge University Press.

Lehiste, I. (1970). *Suprasegmentals*. Cambridge, MA: MIT Press.

Lehiste, I. and G. E. Peterson. (1961). Some Basic Considerations in the Analysis of Intonation. *Journal of the Acoustical Society of America* 33, 419-425.

Letterman, R. (1994). A Phonetic Study of Sinhala Syllable Rhymes. *Working Papers of the Cornell Phonetics Laboratory* 9, 155-181.

Lieberman, P. and S. Blumstein. (1993). *Speech Physiology, Speech Perception, and Acoustic Phonetics*. New York: Cambridge University Press.

Linville, S. (2001). *Vocal Aging*. San Diego, CA: Singular.

Lisker, L. and A. Abramson. (1964). A Cross-Language Study of Voicing in Initial Stops: Acoustical Measurements. *Word* 20, 384-422.

Löfqvist, A. (1975). A Study of Subglottal Pressure during the Production of Swedish Stops. *Journal of Phonetics* 3, 175-189.

Löfqvist, A. and R. McGowan. (1992). Influence of Consonantal Environment on Voice Source Aerodynamics. *Journal of Phonetics* 20, 92-110.

Lombardi, L. (1990). The Nonlinear Organization of the Affricate. *Natural Language and Linguistic Theory* 8, 375-425.

Macdonald, R. and S. Dardjowidjojo. (1967). *A Student's Reference Grammar of Modern Formal Indonesian*. Washington, D.C.: Georgetown University Press.

Mack, M. (1982). Voicing-Dependent Vowel Duration in English and French: Monolingual and Bilingual Production. *Journal of the Acoustical Society of America* 71, 173-178.

Mackay, I. (1987). *Phonetics: The Science of Speech Production*. Boston: Little, Brown and Company.

Maddieson, I. (1984). *Patterns of Sounds*. New York: Cambridge University Press.

Maddieson, I. (1985). Phonetic Cues to Syllabification. In V. A. Fromkin (ed.) *Phonetic Linguistics*. Orlando: Academic Press, 203-221.

Maddieson, I. (1989). Prenasalized Stops and Speech Timing. *Journal of the International Phonetic Association* 19, 57-66.

Maddieson, I. and P. Ladefoged. (1985). "Tense" and "Lax" in Four Minority Languages in China. *Journal of Phonetics* 13, 433-454.

Maddieson, I. and P. Ladefoged. (1993). Phonetics of Partially Nasal Consonants. In M. K. Huffman and R. A. Krakow (eds.) *Nasal, Nasalization, and the Velum*. San Diego, CA: Academic Press, 251-301. (Phonetics and Phonology, Volume 5)

Magen, H. (1984). Vowel-to-Vowel Coarticulation in English and Japanese. *Journal of the Acoustical Society of America* 75, S41.

Major, R. (1992). Losing English as a First Language. *Modern Language Journal* 76, 190-208.

Manuel, S. (1990). The Role of Contrast in Limiting Vowel-to-Vowel Coarticulation in Different Languages. *Journal of the Acoustical Society of America* 88, 1286-1298.

Manuel, S. and R. Krakow. (1984). Universal and Language Particular Aspects of Vowel-to-Vowel Coarticulation. *Haskins Laboratories: Status Report on Speech Research* SR-77/78, 69-78.

McDonough, J. and M. Austin-Garrison. (1994). Vowel Enhancement and Dispersion in the Vowel Space of Western Navajo: A Study of Traditional Navajo Speakers. *UCLA Working Papers in Phonetics* 87, 93-104.

Miller-Ockhuizen, A. (2002). Coarticulatory fundamental frequency effects associated with Ju|'hoansi guttural consonants. In *Proceedings of the First Pan-American/Iberian Meeting on Acoustics*.

Miller-Ockhuizen, A. (forthcoming). Guttural Vowels and Guttural Coarticulation in Ju|'hoansi. Submitted to *Journal of Phonetics.*

Nazar, N. (1991). *Bahasa-Ibu pada Masyarakat Bilingual Indonesia*. Bandung: Institut Teknologi Bandung.

Ogloblin, A. K. (1993). Sistema Yavanskikh Glasnykh: Garmoniya po Pod'emu. *Voprosy-yazykoznaniya* 42, 57-63.

Ohala, J. (1978). Production of Tone. In V. A. Fromkin (ed.) *Tone, a Linguistic Survey*. New York: Academic Press, 5-39.

Ohala, J. and B. Eukel. (1987). Explaining the Intrinsic Pitch of Vowels. In R. Channon and L. Shockey (eds.) *In Honor of Ilse Lehiste*. Providence, RI: Foris Publications, 207-215.

Ohala, J. and M. Ohala. (1993). The Phonetics of Nasal Phonology: Theorems and Data. In M. K. Huffman and R. A. Krakow (eds.) *Nasals, Nasalization, and the Velum*. San Diego, CA: Academic Press, 225-249. (Phonetics and Phonology, Volume 5)

Ohala, M. (1979). Phonological Features of Hindi Stops. *South Asian Languages Analysis* 1, 79-88.

Ohman, S. E. G. (1966). Coarticulation in VCV Utterances: Spectrographic Measurements. *Journal of the Acoustical Society of America* 39, 151-168.

Onn, F. (1980). *Aspects of Malay Phonology and Morphology*. Kuala Lumpur, Malaysia: Universiti Kebangsaan Malaya.

Pater, J. (1995). Austronesian Nasal Subtitution and Other NC Effects. In R. Kager, H. van der Hulst, and W. Zonneveld (eds.) *The Prosody-Morphology Interface*. Cambridge: Cambridge University Press, 310-343.

Peterson, G. and H. Barney. (1952). Control Methods Used in a Study of the Vowels. *Journal of the Acoustical Society of America* 24, 175-184.

Peterson G. and I. Lehiste. (1960). The Influence of Consonantal Environment upon the Secondary Acoustical Characteristics of Vowels. *Journal of the Acoustical Society of America* 32, 693-703.

Pierrehumbert, J. (1980). *The Phonology and Phonetics of English Intonation*. Ph.D. dissertation, MIT.

Pierrehumbert, J. (1990). Phonological and Phonetic Representation. *Journal of Phonetics* 18, 375-394.

Pigeaud, T. (1982). *Javaans-Nederlands Woordenboek*. 's-Gravenhage: M. Nijhoff.

Podesva, R. (1998). An Acoustic Analysis of Buginese Consonants. *Texas Linguistic Forum (Exploring the Boundaries between Phonetics and Phonology)* 41, 147-159. (Proceedings of the 1998 Texas Linguistics Society Conference)

Podesva, R. and N. Adisasmito-Smith. (1999). Acoustic Investigation of the Vowel Systems of Buginese and Toba Batak. *Proceedings of the 14th International Congress of Phonetic Sciences*, 535-538.

Poedjosoedarmo, G. (1974). *Role Structure in Javanese*. Ph.D. dissertation, Cornell University.

Poedjosoedarmo, G. (1988). A Phonetic Description of Voice Quality in Javanese Female Vocalists. *Asian Music: Journal of the Society for Asian Music* 19, 93-126.

Poedjosoedarmo, S. (1982). *Javanese Influence on Indonesian*. Canberra: Australian National University. (Pacific Linguistics, Series D, No. 38)

Port, R. (1981). Linguistic Timing Factors in Combination. *Journal of the Acoustical Society of America* 69, 262-274.

Recasens, D. (1987). An Acoustic Analysis of V-to-C and V-to-V Coarticulatory Effects in Catalan and Spanish VCV Sequences. *Journal of Phonetics* 15, 299-312.

Recasens, D. (1991). An Electropalatographic and Acoustic Study of Consonant-to-Vowel Coarticulation. *Journal of Phonetics* 19, 177-192.

Repp, B. (1984). Categorical Perception: Issues, Methods, Findings. In N. Lass (ed.) *Speech and Language: Advances in Basic Research and Practice, Vol. 10*. Orlando, FL: Academic Press, 244-335.

Rice, K. (1997). Japanese NC Clusters and the Redundancy of Postnasal Voicing. *Linguistic Inquiry* 28, 541-551.

Robson, S. (1992). *Javanese Grammar for Students*. Clayton, Victoria: Center of Southeast Asian Studies, Monash University.

Romaine, S. (1988). *Pidgin and Creole Languages*. New York: Longman.

Romaine, S. (1995). *Bilingualism*. New York: Blackwell.

Rothenberg, M. (1968). *The Breath-Stream Dynamics of Simple Released-Plosive Production*. New York: S. Karger.

Ryan, E.B., H. Giles, and R. Sebastian. (1982). An Integrative Perspective for the Study of Attitudes toward Language Variation. In E.B. Ryan and H. Giles (eds.) *Attitudes towards Language Variation*. London: Edward Arnold, 1-19.

Samsuri. (1958). *Javanese Phonology*. Thesis, Indiana University.

Schiefer, L. (1986). F_0 in the Production and Perception of Breathy Stops: Evidence from Hindi. *Phonetica* 43, 43-69.

Shuy, R. and R. Fasold (eds.). (1973). *Language Attitudes: Current Trends and Prospects*. Washington, D.C.: Georgetown University Press.

Silverman, D., B. Blankenship, P. Kirk, and P. Ladefoged. (1995). Phonetic Structures in Jalapa Mazatec. *Anthropological Linguistics* 37, 70-88.

Smith, C. (1992). *The Timing of Vowel and Consonant Gestures*. Ph.D. dissertation, Yale University.

Söderstein, M. and P-A. Lindestad. (1990). Glottal Closure and Perceived Breathiness during Phonation in Normally Speaking Subjects. *Journal of Speech and Hearing Research* 33, 601-611.

Solé, M-J. (1992). Phonetic and Phonological Processes: The Case of Nasalization. *Language and Speech* 35, 29-43.

Stevens, K. (2000). *Acoustic Phonetics*. Cambridge, MA: The MIT Press.

Suharno, I. (1982). *A Descriptive Study of Javanese*. Canberra: Australian National University. (Pacific Linguistics, Series D, No. 45)

Sumukti, R. H. (1971). *Javanese Morphology and Morphophonemics*. Ph.D. dissertation, Cornell University.

Teoh, B. S. (1988). *Aspects of Malay Phonology Revisited - a Non-Linear Approach*. Ph.D. dissertation, University of Illinois in Urbana-Champaign.

Trudgill, P. (1983). *On Dialect; Social and Geographical Perspectives*. New York: New York University Press.

Uhlenbeck, E. M. (1978). *Studies in Javanese Morpheme*. The Hague, Netherlands: Martinus Nijhoff.

Umeda, N. (1977). Consonant duration in American English. *Journal of the Acoustical Society of America* 61, 846-858.

Vatikiotis-Bateson, E. (1984). The Temporal Effects of Homorganic Medial Nasal Clusters. *Research in Phonetics* (Indiana University, Bloomington) 4, 197-233.

Wang, Y. (2002). *Perception, Production, and Neurophysiological Processing of Lexical Tone by Native and Non-Native Speakers*. Ph.D. dissertation, Cornell University.

Watkins, J. (1998). *Phonetic Correlates of the Register Contrast in Wa*. Presented at the Cornell Linguistics Department Tuesday Colloquium, 10th November.

Watkins, J. (2002). *The Phonetics of Wa: Experimental Phonetics, Phonology, Orthography and Sociolinguistics*. Canberra, Australia:

Research School of Pacific and Asian Studies, the Australian National University. (Pacific Linguistics 531)

Wayland, R., A. Jongman, and S. Gargash. (1994). Acoustic and Perceptual Investigation of Breathy Voice. *Journal of the Acoustical Society of America* 97, 3364.

Wayland, R. (1997). *Acoustic and Perceptual Investigation of Breathy and Clear Phonation in Chantaburi Khmer: Implications for the History of Khmer Phonology*. Ph.D. dissertation, Cornell University.

Wolff, J. (2003). The Role of Canonical Shapes in the Reconstruction of Proto-Austronesian Phonology. *Cornell Working Papers in Linguistics* 19, 264-278.

Wolff, J. and S. Poedjosoedarmo. (1982). *Communicative Codes in Central Java*. Ithaca, NY: Cornell University Southeast Asia Program.

Yallop, C. (1982). The Phonology of Javanese Vowels. In A. Halim, L. Carrington, and S.A. Wurm (eds.) *The Third International Conference on Austronesian Linguistics, vol. 2: Tracking the Travelers*, 299-319. (Pacific Linguistics, Series C, No. 75)

van Zanten, E. (1989). *The Indonesian Vowels: Acoustic and Perceptual Explorations*. Ph.D. dissertation, Leiden University.

Zec, D. (1995). Sonority Constraints on Syllable Structure. *Phonology* 12, 85-129.

Zsiga, E. (1995). An Acoustic and Electropalatographic Study of Lexical and Postlexical Palatalization in American English. In B. Connell and A. Arvaniti (eds.) *Phonology and Phonetic Evidence*. New York: Cambridge University Press, 282-302. (Papers in Laboratory Phonology IV)