The Phonetics and Phonology of the Lopit Language

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September 2017

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Submitted in total fulfilment of the requirements of the degree of Doctor of Philosophy

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Abstract

This thesis is an investigation of the sound system of Lopit, an Eastern Nilotic (Nilo-Saharan) language traditionally spoken in South Sudan. The primary aim of this study is to develop a phonetically-based description of aspects of Lopit segmental and tonal phonology, with a focus on the Dorik variety of the language.

This is first approached via analyses of phonological and morphological patterns in Lopit, using data collected during extended fieldwork with members of the Lopit community in Melbourne, Australia. A number of hypotheses regarding Lopit phonological contrasts and processes are put forward, including proposals for nine monophthongs, an inventory of 27 consonants, and three tones used for both lexical and grammatical distinctions. Some differences in the number and nature of contrasts are found compared to observations in the limited existing materials on Lopit.

Four production experiments are then undertaken to examine the acoustic and articulatory evidence for three phenomena of particular interest. The first is the phonological feature 'Advanced Tongue Root', widely attested in African languages and here suggested to distinguish monophthongs /i, e, o, u/, labelled [+ATR], from /ɪ, ɛ, a, ɔ, ʊ/, labelled [-ATR]. The results of an acoustic experiment reveal lower first formant frequencies as the primary correlate distinguishing [+ATR] from [-ATR] vowels, and a following ultrasound-based experiment shows that vowels in the [+ATR] set have a more anterior tongue root position than those in the [-ATR] set.

Length contrasts proposed for selected obstruents and sonorants include a contrast between singleton glides /w, j/ and geminate glides /wː, jː/, a typologically uncommon distinction which has received little phonetic attention crosslinguistically. The results of an acoustic investigation of Lopit glides show that duration is a robust correlate of glide contrasts at the same place of articulation, with the putative geminates being significantly longer. Furthermore, they have a more constricted articulation, as evidenced by lower first formant frequencies and lower root-mean square amplitude values.

An acoustic experiment testing the proposed contrast between High, Low and Falling tones confirms that these three tones are distinct, with higher fundamental frequency values for the High compared to Low tone, and a trajectory of high to low values for the Falling tone. It is also shown that the fundamental frequency and duration characteristics of these tones are sensitive to the tonal context in which they occur.

These experiments contribute the first phonetic data on Lopit, and, combined with the phonological and morphological analyses, significantly increase the level of description of an under-documented Nilo-Saharan language. This study also develops typological understandings of the phonetic implementation of ATR contrasts, the status of length distinctions among glides, and Nilotic tone systems, and demonstrates the value of incorporating phonetic data into the documentation of African languages.

Declaration

This is to certify that

1. the thesis comprises only my own original work towards the PhD,
2. due acknowledgement has been made in the text to all other material used,
3. the thesis is fewer than 100,000 words in length, exclusive of tables, maps, bibliographies and appendices.

Rosey Billington, September 2017

Acknowledgements

My sincerest thanks to my supervisors, Janet Fletcher and Brett Baker, for their invaluable guidance, encouragement and patience, and for inspiring me to continue pursuing my interest in linguistic phonetics. A heartfelt *humu bino* to the members of the Lopit Community Association of Australia who contributed their time and knowledge to this project in many different ways, especially Arkangelo Lobong Lohine, Daniel Afelino, Victor Hilibong, Elizabeth Amedeo and Jane Lobalu and their families for welcoming me into their homes and pairing their expertise with such enthusiasm for this work. Thanks are also due to members of the Lopit Community in Kakuma and to others in South Sudan and Uganda who offered their input and encouragement from afar. Thank-you to Jonathan for collaborating in the wider language documentation project this work is part of, and for many productive discussions over the years.

I am grateful to Hywel Stoakes for his assistance in the collection of ultrasound data, and helpful advice at various points along the way. Thanks to Gavin Nebauer for his assistance in the recording studio. Thank-you to Debbie Loakes for advice and support, and for organising the departmental Phonetics and Phonology workshops which have allowed me to receive useful feedback and suggestions from colleagues on many occasions. To John Hajek, Barb Kelly, Rachel Nordlinger, Nick Thieberger, Jill Wigglesworth and other academic staff in the School of Languages and Linguistics, thanks for the inspiration, practical advice and encouragement. Thanks also to Simon Musgrave and Kate Burridge at Monash University; Simon for first introducing me both to Sudanese languages and to phonetic research, and Kate for kindling my interest in linguistics.

My thanks to the many people elsewhere who have provided feedback, information and insights relating to this work. Thanks to Tim Stirtz and Jackie Marshall from SIL for sharing Lopit language materials with me, and to Darryl Turner for an enjoyable discussion of some of these while I was visiting the University of Edinburgh. Sincere thanks to Bert Remijsen at the University of Edinburgh for stimulating discussion of Nilotic phonetics and phonology as well as technical suggestions, and to Bob Ladd for thoughtful discussions of tone. Thanks to John Esling and colleagues at the University of Victoria, Gerrit Dimmendaal and colleagues at the University of Cologne, and Doris Payne and colleagues at the University of Oregon for conversations about aspects of this work. Thanks to Isao Murahashi for sharing the findings of his ongoing research relating to Lopit culture. Thanks to the Honours students in the University of Melbourne Field Methods class on Lopit for their collective efforts during the early stages of this project.

To past and present members of the Phonetics Laboratory at the University of Melbourne, thank-you for contributing to such a positive and enjoyable work environment. Special thanks to Joshua Clothier, Simone Graetzer, Katie Jepson, Eleanor Lewis, Olga Maxwell, Amos Teo, and Mengyue Wu as well as Hywel and Debbie for the camaraderie and tea breaks. Thanks also to past and present members of the Language Documentation Laboratory, and to Sara Ciesielski, Brighde Collins, Lucy Davidson, Daniela Diedrich, Bill Forshaw, Lauren Gawne, Kate Horrack, Jill Vaughan and Aidan Wilson for many convivial discussions. Thanks to the Languages and Linguistics Postgraduate Club for providing a wider network of support and information. Thanks also to the professional staff in the department for administrative support, especially Belinda Hofmeyr, Letty Nieuwenhuizen, Gabrielle Grigg, Nadine Forsythe and Charlotte Morgans.

Many thanks to my family and friends: to my parents and grandparents for their encouragement long before this stage, to Chris, Ana, Kathryn, Michael, Philippa, Deb, Ian, Tim, Kim and Pip for their support and interest and especially to Chris for technical help, and to the many friends whose company was a welcome distraction. Thanks most of all to Jason for his love, companionship and keen proofreading eye.

Funding support from various sources is gratefully acknowledged: An ARC Postgraduate Award, the School of Languages and Linguistics Research Data Collection Support scheme, the Faculty of Arts Graduate Research in Arts Travel Scheme and Overseas Research Experience Scholarship, an Endangered Language Fund Language Legacies grant, ARC grant DP0984419, and the ARC Centre of Excellence for the Dynamics of Language.

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Chapter 1

Introduction to the Study and the Lopit Language

1.1 Introduction

This thesis is an investigation of the sound system of Lopit[1], an Eastern Nilotic (Nilo-Saharan) language traditionally spoken in the Republic of South Sudan. The primary aim of this study is to produce a phonetically-based analysis of Lopit phonology, with a focus on selected vowel, consonantal and tonal phenomena in the Dorik variety of the language. The linguistic record of Lopit was, until very recently, extremely limited, and as such the early stages of the project focus on the collection of lexical and morphosyntactic data, primarily via extended work with members of a community of Lopit speakers living in Melbourne, Australia. Analyses of these data then inform the development of specific hypotheses regarding the segmental and tonal inventory of Lopit, and enable the design of more targeted investigations which test these using experimental phonetic approaches. The experimental phonetic analyses relate to three phenomena of particular interest: the possible presence of a contrast in the Lopit vowel system on the basis of the phonological feature 'Advanced Tongue Root', putative length-based contrasts for a number of Lopit consonants including palatal and labial-velar glides, and tonal contrasts used for lexical distinctions but also with a significant grammatical role. This

[1]ISO 639-3: `lpx`; Glottocode: `lopi1242`. In the literature, this language name also appears as *Loppit*, *Lopid*, *Lofit*, *Lafit*, *Lafiit*, *Lafite*. All the participants in this project use the form *Lopit*, in addition to the name *Lodongie* and occasionally *Lopitijei*. The latter two are reportedly only used by Lopit people, while the preceding forms are also used by external groups.

wide-ranging approach is motivated by a desire to bring more phonetic data into discussions of African phonologies, develop the crosslinguistic understanding of features of particular typological interest, and contribute more comprehensive records of under-documented Nilo-Saharan languages to better inform the understanding of their genetic and areal relationships.

The Republic of South Sudan has been an independent country since a 2011 referendum resulting in secession from the northern Republic of Sudan. Like other countries in the linguistically diverse East African region, South Sudan is home to many languages; an estimated 68 languages are currently in use, and a further 76 are used in the northern territory from which it seceded (Lewis, Simons & Fennig, 2016). Many if not most of these remain under-described, a situation influenced in no small part by the many decades of civil war in the former Sudan. Descriptive accounts, particularly of minority languages, are limited in their availability and scope, and as such the understanding of phonological, lexical and morphosyntactic patterns of Sudanese languages is in many cases only very preliminary. The paucity of comprehensive and recent work on these languages is reflective of the wider language documentation situation in Africa, in which the least well-documented languages are those with small, vulnerable or remote speaker populations (Sands, 2009). The unbalanced nature of linguistic description for African languages has implications for the understanding of the diversity of linguistic patterns across the continent, and in particular, for the understanding of African sound systems. While descriptions of the segmental and tonal phenomena of African languages have been enormously influential in phonological theory, they have largely focused on the many languages of the Niger-Congo phylum, and have only infrequently been supplemented with detailed phonetic analyses. However, it is clear that such analyses have much to offer, both in terms of quantitative evidence supporting (or discounting) phonological observations, as well as new insights which develop typological understandings (Pulleyblank & Allen, 2013).

At the outset of this study, available materials on the Lopit language were limited to two wordlists (Driberg, 1932; Vossen, 1982), one with some accompanying phonological observations (Vossen, 1982), and later supplemented by the more detailed phonological observations in Turner (2001) and further work emerging in recent years (e.g. Stirtz, 2014b; Moodie, in progress). These materials point to a number of typologically interesting linguistic features which remain poorly understood across languages of the African continent and elsewhere, and which warrant closer descriptive attention. Among these are the possible 'Advanced Tongue Root' vowel contrasts, glide length contrasts and tonal distinctions which, as noted, have emerged as the focus of the current work. In the Eastern Nilotic language family, and among Nilo-Saharan languages more generally, Lopit is not unique in having these types of proposed phonological characteristics, but their phonetic implementation has received very limited attention across these languages, and none so far for Lopit. Furthermore, the phoneme inventory of Lopit is not clearly established; existing work varies with regard to the number and nature of segmental and tonal contrasts proposed for Lopit, and has for the most part only had limited data to draw on for linguistic analyses. The present study contributes the first phonetic data on Lopit, and, combined with the phonological and morphological analyses, significantly increases the level of description of an under-documented Nilo-Saharan language.

1.2 Structure of this Thesis

The remainder of this chapter provides background information on the Lopit people in 1.3, followed by details pertaining to the Lopit language in 1.4, including a summary of previous work and linguistic features in 1.4.2 and 1.4.3. In 1.5.1, I discuss the motivations for this study, then introduce the research aims and questions in 1.5.2, before addressing the scope of this work in 1.5.3. In 1.6, I turn to the general methodological approach, including an overview of participants in 1.6.1, a discussion of the research context and approaches to data collection and phonological analyses in 1.6.2, and a brief introduction to the quantitative phonetic analyses, treated in more detail in later chapters, in 1.6.3.

Chapter 2 provides an overview of the main characteristics of Nilotic sound systems, and includes more detailed discussions of previous observations for Lopit and related languages. It gives a sense of the general tendencies across the three branches of Nilotic in terms of segmental and tonal inventories, and situates Lopit within these based on available information, while highlighting features which are of particular interest, and particularly worthy of further exploration. These underpin the research questions which guide this thesis, first introduced in 1.5.2 and then discussed in more detail in 2.5. Chapter 3 constitutes an analysis of Lopit phonology based on data collected in the course of this study, following the approach noted in 1.6.2.2 and then discussed further in 3.2. This chapter outlines the vowel, consonantal and tonal contrasts observed for the Dorik dialect, together with observations on phonotactic patterns and phonological processes.

Selected proposals made in Chapter 3 then lead into three experimental chapters which contribute quantitative data to analyses of the Lopit sound system: Chapter 4, focusing on 'Advanced Tongue Root' contrasts among vowels; Chapter 5, exploring length contrasts among glides; and Chapter 6, investigating tonal contrasts. Each chapter begins with an overview of the relevant literature which expands on the Nilotic-focused observations of Chapter 2, and draws together the pertinent phonetic findings of cross-linguistic studies. Following the presentation of specific hypotheses, each chapter continues with a discussion of the relevant methods used, followed by detailed results and accompanying discussion. The key findings of the three experimental chapters and the phonological analysis chapter are then drawn together in Chapter 7, and followed by a discussion of the wider contributions of this work, and potential future directions.

1.3 The Lopit People

1.3.1 Population and location

The Lopit people traditionally live in the slopes and foothills of the Lopit Mountains, a low-lying range on the plains of Eastern Equatoria State in the Republic of South Sudan. The Lopit, who also use the endonym *Donge* ('mountain'), are a minority group of South Sudan, and to date very

Figure 1.1: Map showing Torit, E. Equatoria, South Sudan (adapted from Wikimedia Commons [CC-BY-3.0]; Spesh531, NordNordWest).

little has been written about their language and their culture. A 1995 survey (Randal 1995, cited in Lewis, Simons & Fennig, 2013) estimates the population of the Lopit Mountains to be around 50,000 people, though reliable population data for this region is limited as a result of decades of civil war and the associated disruption to administration in the former Sudan.

Estimates based on data collated from other sources suggest much lower numbers (Grüb, 1992), while the Lopit people themselves provide more generous estimates, suggesting there are 70,000 to 100,000 Lopit distributed throughout 55-60 villages (Turner, 2001, and reported to me in the course of my own work). Neighbours to the Lopit include the Päri to the north, Bari to the north-west, Lokoya to the west, Otuho to the west and south, Dongotono to the south, and Toposa and Boya (Longarim/Laarim) to the east. The Tennet (Irenge) people also live amongst the Lopit, in five villages in the northern part of the mountain range, and are accepted as Lopit. The Tennet settled in the Lopit Mountains after separating from other Surmic groups such as Murle, Didinga and Boya during a migration (Dimmendaal, 1983a), which the Lopit participants in this study estimate to have been in the 18th century.

The Lopit people have been considerably affected by the many years of war and unrest, and large numbers of Lopit have been internally and externally displaced. This has been the case for numerous ethnolinguistic groups of South Sudan. Many Lopit live in the nearby city Torit, 60km southwest of the Lopit Mountains, and in Juba, the current capital of South Sudan. Some Lopit men who are or have been affiliated with the Sudan Peoples Liberation Army have spent time in states further north, such as Jonglei State. Other Lopit people travelled long distances to seek refuge during times of war, and currently live in different countries within Africa as well as overseas. The Lopit diaspora includes populations in Kenya, Uganda, Nigeria, Egypt, Libya, Canada, the United States, the United Kingdom, and Australia, including Melbourne, the field site for the present study. Lopit people are therefore numerous, but dispersed, with many now living and growing up outside the traditional Lopit homeland.

1.3.2 History and culture

Little is known about both the recent and ancient histories of many cultural groups of South Sudan, but, like much of East Africa, it is a region with a deep history of many waves of migration. The Lopit, Otuho, Dongotono, Lokoya and Lango[2] are thought to have a common origin as the Proto-Lotuko people (Vossen, 1982), although Driberg (1932) speculates that the Lopit, Dongotono, Lokoya and Lango, as the 'hill-dwelling groups' may not be related to the Otuho but instead be the original inhabitants of the plains below the Lopit mountains.[3] Speculation based on Otuho oral histories suggests that the Proto-Lotuko people may have originally immigrated from somewhere in south-western Ethiopia, to the north-east of where they now reside (Vossen, 1982, pp. 43–48, also citing Hatulang, n.d, and Muratori, 1938), though collected stories are far from consistent (Seligman & Seligman, 1932; Grüb, 1992). However, views based on linguistic evidence suggest that these groups, as part of the Proto-Lotuko-Maasai, had a homeland in the region where Uganda, Kenya and Sudan come together (Ehret et al. 1974b, cited in Vossen, 1982, p. 43), perhaps originating in Uganda or Kenya and moving northwest from there (Jurey, 1981, p. 13). Across the Eastern Nilotic ethnolinguistic groups, Vossen (1982, pp. 457–487) provides the most comprehensive discussion of historical inferences based on linguistic data. The more distant connection between Eastern, Western and Southern Nilotic groups as Proto-Nilotic is widely accepted (Dimmendaal, 1988).

Different Nilotic groups have many cultural and linguistic similarities. In particular, the social organisation into age-sets and the institution of the 'rainmaker' are shared by many Nilotic groups, and have also been borrowed by non-Nilotic groups in South Sudan. Lopit society is structured around exogamous clans of patrilineal descent, and these are cross-cut by the different age-sets to which males and females belong. The children or adults in each age set have specified roles and responsibilities according to their age-set and gender. When adolescent men are initiated into manhood, they become part of the *monyomiji*, lit. 'fathers of the village' the ruling generation made up of several age-

[2] Not the same as the Lango of Uganda.

[3] Driberg hypothesises that these four groups were driven into the mountains and isolated from each other by an inundation of Otuho-speaking immigrants into the plains, from then on falling under the linguistic influence of the Otuho.

sets. Amongst the *monyomiji*, the highest authority is the rainmaker, *habu na hai* 'king of the rain' responsible for bringing the rains that are vitally important for agricultural success. Rainmaking is a hereditary appointment, typically held by a man born of a father and mother both from rainmaking lines, though a woman may also hold the position. On rare occasions, if the rainmaker is not adequately performing his responsibilities, the repercussions may be fatal and another rainmaker will then take his place (Jurey, 1981; Grüb, 1992; Seligman & Seligman, 1925, 1932).

Religious and social activities are closely linked to agricultural operations, and Jurey observes that "culture and agriculture are an organic whole" (Jurey, 1981, p. 24). The agricultural calendar determines the timing of major festivals, hunts, and other events, all of which are celebrated with specific dances and music, with drums as the primary instrument and various types of bells and horns used as well. Agricultural production is tied to social structures and obligations, which determine the division of labour and distribution of produce. The Lopit mountains, which reach 1,900m at their highest point, provide a suitable environment for a range of crops to be cultivated. Agriculture is of prime economic and sociocultural importance amongst the Lopit. Some crops are grown on the fertile upper slopes of the mountains, or *nyarrat*, and others on the plains or *gumi* at the base of the mountains, where rainwater runoff collects during the wet season (around April-October). Primary crops are sorghum (many varieties), bulrush millet and groundnuts, and additional staples include maize, finger millet, sweet potatoes, yams, beans and sesame. Vegetables such as okra, pumpkins, and cucumbers are widely grown, and a range of leafy green vegetables are also popular. In additional, many wild foods such as coconuts, shea nuts, bamboo roots, figs, mushrooms and honey are gathered from the broad-leaf forests. Some Lopit also construct hives for bee-keeping. The Lopit keep domesticated animals, the most prized of which are cattle, important both as a measure of wealth and for their immense practical value. Goats, sheep and chickens are also kept. Hunting takes place during the dry season (around November to March) with traditional game including buffalo, elephant, giraffe, rhinoceros, gazelle, ostrich, and various species of antelope. During the wet season people fish in the swampy areas north of the Lopit mountains and in seasonal rivers and lakes. (See Jurey, 1981 for more detail on culture and agriculture amongst the Lopit people at Lohutok, ongoing work by Murahashi, 2013 relating to Lopit social organisation, and Grüb, 1992, Seligman & Seligman, 1925 and Seligman & Seligman, 1932 for information on the closely-related Otuho people).

1.3.3 Languages

The main language spoken by the Lopit people is the Lopit language, also referred to as *Lodongie*. However, other languages are also known and used by Lopit people, contributing to a somewhat complex sociolinguistic situation which is worth illustrating given the potential for these other languages to have linguistic influences on Lopit itself. The Tennet (Irenge) people who settled in the northern part of the Lopit mountains are considered Lopit and use the Lopit language but also maintain the use of their own language, and therefore many Lopit with Tennet family connections also know the Tennet language. Tennet is not a Nilotic language; it is from the Surmic branch of Eastern Sudanic, within the Nilo-Saharan phylum (Randal, 1998; Dimmendaal, 1983a). A small group of Bari speakers also settled in a village in the northern part of the Lopit mountains some time ago, but it is believed that there are no longer any remaining speakers there. Bari is an Eastern Nilotic language spoken in the Juba area.

Other languages from the region play a more significant role in Lopit speakers' lives. Many Lopit people know and use Otuho, the language spoken by their neighbours on the plains. This is likely acquired either through schooling in Torit or in the southern Lopit area, or through interactions with Otuho speakers in Torit and elsewhere. There are no formally established schools in the northern parts of the Lopit Mountains, and at the time this project began, no substantial development of language and literacy materials had yet taken place for Lopit.[4] Primary schools in the southern parts have largely used Otuho as the language of education, early missionaries having decided that Otuho was similar enough to Lopit to be a suitable conduit for literacy and religious instruction.

[4] However, some preliminary materials were compiled by Turner (2001) following workshops with some Lopit speakers in Kenya, and more recent workshops with Lopit speakers in South Sudan are part of ongoing work to develop Lopit language resources (Ladu, Nartisio, Bong, Odingo & Gilbert, 2014a, 2014b; Ladu, Nartisio, Bong, Odingo, Gilbert & Stirtz, 2014; Stirtz, 2014b). These are discussed in 1.4.2 and in later sections.

Some Lopit people feel that their language is threatened by Otuho. Possibly as a result of the decisions made by early missionaries, a process of language shift has reportedly been taking place in the southern Lopit area, with the use of Otuho becoming widespread. While the picture is far from clear, anecdotal reports suggest that some southern Lopit villages have shifted entirely to Otuho, while others are substantially influenced by it.

Many Lopit also speak Juba Arabic, a creole of South Sudan (Manfredi & Petrollino, 2013). The Arabic-based variety includes influences (particularly in vocabulary) from Bari and other closely-related Eastern Nilotic language varieties spoken in and around the Juba area, in addition to some influences from other Nilotic and non-Nilotic languages. Juba Arabic is the lingua franca among the diverse ethnolinguistic groups of south-eastern South Sudan, and its role as a lingua franca was (and still is) important for communication in cities such as Juba and Torit, as well as in the refugee camps that large numbers of South Sudanese have lived in for many years, and in other diaspora communities. Some older Lopit men also speak Standard Sudanese Arabic, which was previously used in schools and other contexts in what is now South Sudan, and some additionally have knowledge of other Arabic varieties, such as Egyptian Arabic. Various other languages that some Lopit people have knowledge of and can use to some extent include KiSwahili, Luganda, and Acoli, encountered during time in refugee camps, and majority languages of South Sudan such as Dinka and Nuer, encountered in similar contexts or during interactions with members of the Sudan People's Liberation Army (SPLA), who at times during the war used the Lopit Mountains as a base of operations and also recruited from communities there. In sum, speakers of Lopit also have a range of linguistic resources at their disposal, and their use of these linguistic resources varies according to their current and historical social networks.

1.4 The Lopit Language

1.4.1 Speakers and dialects

Lopit is a minority language, but actual speaker numbers are difficult to ascertain. The Lopit population estimate of 50,000 noted above in 1.3 is that used as the estimated number of speakers in the current entry for the Lopit language in the Ethnologue, but it is interesting to note that while the 2009 edition (Lewis, 2009) attaches this figure to the Lopit Hills (Mountains), editions since Lewis et al. (2013) have retained the same figure but revised the location to “north end of Lopit Hills”. Presumably this reflects the aforementioned possible transition to Otuho in the southern parts of the Lopit Mountains. However, separate to the the possibility of language shift in some areas, the language situation is not clear. While Lopit is not considered to be an endangered language, the civil war has likely had effects on the transmission of cultural and linguistic knowledge, both as a result of significant loss of life, including among those who would currently be considered elders of the community, and also the different linguistic environment experienced by children growing up in refugee camps, and the effects of population movement more generally. These matters all require further attention.

Lopit has six dialects, according to the speakers I have worked with: Ngabori, Dorik, Ngutira, Lomiaha, Lohutok, and Lolongo (see Figure 1.2).[5] Based on preliminary work with speakers of five of these dialects, and as indicated by Stirtz (2014b), it appears that the dialects have similar segmental phonologies but many examples of vowel and consonant category shift across the dialects, as well as some tonal variation. There are also various lexical differences between the dialects, including for pronouns, and some indications of grammatical differences. The Lopit speakers tend to divide the dialects into two main groups: Northern Lopit and Southern Lopit. Central Lopit is also sometimes referred to as a distinct area,

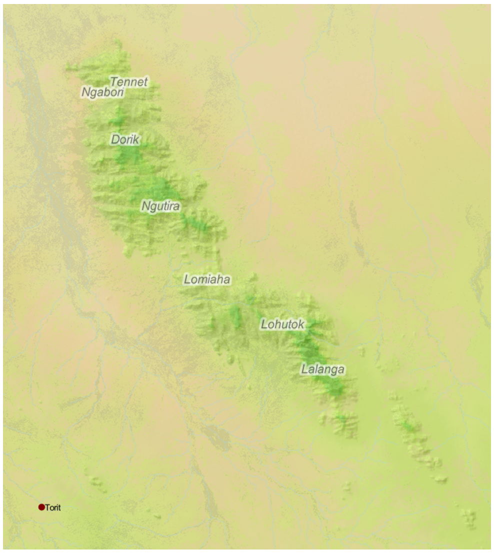


Figure 1.2: Map showing the Lopit Mountains with approximate locations of Lopit dialect areas, and of the Tennet language (own creation).

[5]Dialect names vary depending on the pronunciation used by different Lopit groups, and different orthographic preferences; variants include Ngaboli, Ngotira, Lemiaha, and Lalanga.

corresponding to where the Ngutira dialect is spoken, and is sometimes divided into East and West, with some reports of linguistic differences between the two. The northern dialects, Ngabori and Dorik, are considered by many speakers to be the most conservative dialects of the language, while the southern dialects are considered by some to have substantial influences from the neighbouring Otuho language. These influences include lexical borrowing as well as some structural changes, as observed by the Lopit speakers themselves, and in my own research so far. It is also possible that the closer linguistic affiliation of southern Lopit-identifying communities to Otuho is not a recent phenomenon (but interacts with more recent influences); in some early anthropological and linguistic research, for example, the Lomiaha are mentioned as a separate ethnolinguistic group to both Lopit and Otuho, but with historical ties to Otuho communities (e.g. ?, ?, p. 154, Muratori, 1938, p. xix). As discussed above in 1.3.3, many Lopit speakers are multilingual, and may also use borrowings and potentially other features from a number of different languages.

1.4.2 Classification and previous work

Figure 1.4: Map showing the distribution of African linguistic phyla (according to Greenberg's classification), with Nilo-Saharan languages in yellow (from Wikimedia Commons [CC-BY-2.5]; Mark Dingemanse).

Lopit is classified as part of the Eastern Nilotic language group, within the Eastern Sudanic branch of the Nilo-Saharan language group. A 'linguistic family tree' for Lopit is presented in Figure 1.3. This is based on data from Ethnologue (Lewis et al., 2013), which, for the Eastern Nilotic languages at least, is informed by the hypotheses put forward by Vossen (1982, 1983) in his comparative reconstruction of Eastern Nilotic, and subsequently taken up by Bender (1997) in his most comprehensive formulation of the Nilo-Saharan

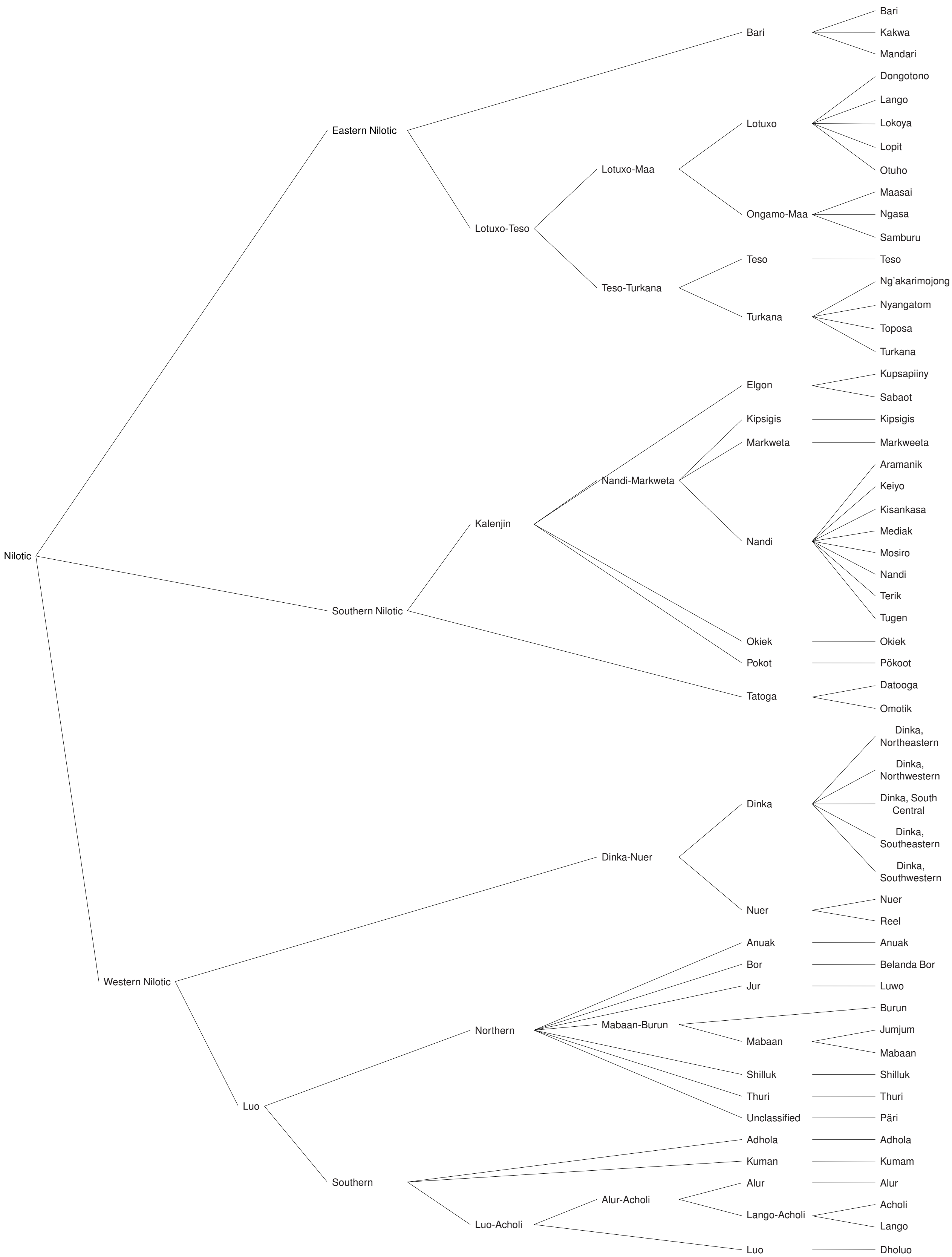


Figure 1.3: The Nilotic language family (based on Lewis, Simons & Fennig 2013).

phylum.[6] Of the four phyla proposed for the African continent (J. H. Greenberg, 1963), Nilo-Saharan (shown in Figure 1.4) is one of the most debated and least agreed-upon in terms of the groupings of its constituents. The major competing theories of the internal relations of this phylum are Greenberg's classification, which is still widely used; Bender's (1997) classificatory system and slight later revisions (Bender, 2000); and Ehret's (2001) approach, which does not differ a great deal for the Eastern Nilotic languages, though groupings elsewhere are quite different.[7] As Sands (2009, p. 568) notes, "there seems to be no consensus among scholars between the Nilo-Saharan classifications", but Bender's (1997) approach is probably the most widely-accepted, or perhaps the most well-developed.

Of the Nilo-Saharan groupings, the 'core' appears to be the East Sudanic group, into which Lopit is classified, and the Nilotic group within this "served as a nucleus from which the phylum was built up" (Bender, 1997, p. 58). Pre-Greenberg (1950), the conceptualisation of what is now known as the Nilotic family involved a combination of two or three sub-families known variously as Nilo-Hamitic or Niloto-Hamitic (e.g. Struck, 1911), Niloto-Sudanic (Westermann, 1912), or Paranilotic (Tucker & Bryan, 1966). These groupings were largely based on outmoded concepts "clinging to racist-cultural criteria" (Bender, 1997, p. 59), rather than exclusively linguistic data, but the introduction of Köhler's (1950) 'West', 'East' and 'South' Nilotic families, adopted by Greenberg (1963), has become the accepted division of the Nilotic family on linguistic grounds.

While many of the disagreements regarding the sub-division of the Nilo-Saharan constituents relate to languages outside the Nilotic grouping, the classifications within the Nilotic family are often based on minimal data, and, as is the case across all four phyla posited for the African continent, a realistic understanding of the relationships between

[6]The languages of the African continent are generally conceived of as falling into four major phyla, based on Greenberg's "complete genetic classification of the languages of Africa" (J. H. Greenberg, 1963, p. 1), in which Niger-Kordofanian, Afroasiatic, Khoisan and Nilo-Saharan are put forward as the four major linguistic groupings. The phyla, while still widely used as referential groupings, are not considered to adequately represent the realities of macro linguistic relationships on the African continent, but no other model of the large-scale groupings has gained the same currency.

[7]Ehret (2001) does use different terminology, however; his approach would classify Lopit as Nilo-Saharan >Sudanic >Northern Sudanic >Sahelian >Eastern Sahelian >Kir-Abbaian >Kir >Nilotic >Eastern Nilotic >Teso-Maasaian >Lotuko-Maa >Lotuko.

languages is hampered by a lack of close scholarly attention across languages, particularly for smaller languages. There are four other languages in the immediate Lotuxo family with Lopit: Dongotono, Lango, Lokoya, and Otuho,[8] all spoken in the plains and hills surrounding the Lopit Mountains. Of these languages, Otuho is the only one that has been studied to any extent, primarily in early work by Italian missionaries (Muratori, 1938). There is not yet a clear picture of the linguistic relationships between these five languages, though they certainly have much in common. However, given the complex migration history of East Africa, which remains poorly understood, and the associated high degree of linguistic transfer, or areal mixing, between unrelated languages, the possibility of linguistic relationships resulting from conversion through geographic proximity, rather than diversion through geographic separation, must be borne in mind. Patterns of migration, language contact and multilingualism have not been studied for Lopit and related languages, but evidence of areal phenomena suggests some of the linguistic effects these may have had more generally for Nilotic and other Nilo-Saharan languages in the region (Dimmendaal, 1995, 2017). These possibilities present a challenge for historical linguists attempting to tease apart and reconstruct connections between different languages and groups of languages, particularly at the higher-level groupings where the time depth of a posited branch in the family tree is substantial. However, as new, more comprehensive synchronic data become available, these understandings can be refined.

Previous materials on Lopit are limited. An early mention of the language by Raglan (1922), in his treatment of the Otuho language, suggests that Lopit and other nearby languages are dialects of Otuho, and it is this claim that Driberg (1932) investigates with his collection of wordlists. Driberg's work includes a Lopit wordlist of 107 items and some brief comparisons between languages of the Lotuko area. For Lopit, Driberg (1932, p. 606) concludes that the language shows remarkable similarities to Dongotono, and some evidence of assimilation to Otuho, but emphasises that his data were collected in a southern part of the mountain range and that there were likely to be more striking dif-

[8]Also frequently called Lotuko, Latuka and Lotuxo. In this thesis I used Otuho to refer to the language, following the language entry in the Ethnologue (Lewis et al., 2016), and use Lotuxo to refer to the immediate grouping of five languages.

ferences for the northern Lopit dialects. Muratori's grammar of Otuho contains some notes on the relationships between different Nilotic languages, and among his proposed groupings, there is one group containing Lopit and Dongotono, a separate group containing Lokoya and Lango, and another group for Lotuxo (1938, p. 495). In later work, Vossen (1982) presents wordlists for various Eastern Nilotic languages, for the purposes of linguistic comparison and historical reconstruction. These materials include a Lopit wordlist of 156 items (1982, pp. 126–149; see p. 106 for English glosses), collected with a speaker from the central area. Through his comparative work, Vossen was able to expand on earlier observations about the relationships between Eastern Nilotic languages, and also produced some basic phonological sketches for the languages studied. In Vossen's analyses, Lopit, Dongotono and Lokoya are considered to be similar enough to group together for a phonology sketch, while Otuho is treated separately, but all of the Lotuxo languages are treated together in notes on morphology.

Of the languages in the Lotuxo family, only Otuho has received more than cursory descriptive attention, though Muratori's (1938) grammatical insights are less than comprehensive by modern standards. Coates (1985) has produced a more recent and detailed phonology sketch for Otuho, with orthographic notes. Following a similar model, Turner (2001) conducted some work with various Lopit speakers, particularly from the south and central areas, in Kenya and Uganda. The resulting unpublished phonology sketch, based on almost 500 words, is a significant contribution. Other work has emerged in recent years, concurrent with this project. Students in a 2011 Linguistic Field Methods class at the University Melbourne have contributed to data collection and preliminary description of different aspects of Lopit grammar through their work with a Lopit language consultant, and ongoing work by Moodie (2012, in progress) focuses on analyses of a range of Lopit morphosyntactic features, discussed further in 1.4.3. In addition, workshops with five Lopit speakers (representing five of the six dialects) have taken place in South Sudan, as part of an ongoing project to develop language materials, and have resulted in trial spelling and grammar books, and associated materials (Ladu, Nartisio, Bong, Odingo & Gilbert, 2014a, 2014b; Ladu, Nartisio, Bong, Odingo, Gilbert & Stirtz, 2014). These include a description of the phonology, focusing on the Ngutira variety in particular, based on 285 nouns in singular and plural form, and 60 imperative verbs (Stirtz, 2014b). Comparisons of segmental patterns between dialects are also presented [9]

1.4.3 Linguistic features

1.4.3.1 Morphology and syntax

In early work containing some Lopit language data, observations on Lopit morphosyntax were limited to passing mention of word order and some speculation regarding possible affixes (Muratori, 1938, p. XVII, Vossen, 1982, pp. 213–219). More detailed grammatical descriptions have emerged in work concurrent with the present study. The following remarks are based on research by Moodie (e.g. Moodie, 2012; Moodie, in progress; and associated work) and some information can also be found in Ladu, Nartisio, Bong, Odingo and Gilbert (2014a, 2014b); Ladu, Nartisio, Bong, Odingo, Gilbert and Stirtz (2014). Lopit is a head-marking language with a basic word order of VSO (VAO). Nouns are classified into two genders, masculine and feminine. Gender is largely indicated via agreement with demonstratives and possessives, and sometimes marked on the noun, for example as a result of derivational processes. The feminine gender is most common, with the masculine gender used primarily for male people and animals, and small creatures and objects. There is also some flexibility in nominal gender, with shifts from feminine to masculine (or vice versa) possible depending on the size of the referent. Nouns are also marked for case; in Lopit, the nominative is the marked case, and differentiated from the absolutive by a change in the tonal pattern across the noun (Moodie & Billington, 2015). As is typical for Nilo-Saharan languages, number marking in Lopit is highly irregular. It involves a range of possible morphemes in what can be described as a tripartite number marking system; nouns may be unmarked in the singular, and grammatically marked in the plural, or, for objects typically found in pairs or groups, they may be unmarked in the plural and marked in the singular. For other nouns, both the singular and plural may appear to be morphologically complex (Moodie, 2016). Verbs in Lopit fall into two main

[9] Thanks to Tim Stirz and Jackie Marshall from SIL-South Sudan for sharing the materials by Turner (2001) with me, and to Tim for also sharing the materials emerging from workshops in Juba.

classes; one in which the stem is characterised by a root-initial close front vowel, and one in which the stem is consonant-initial. These differing structures have implications for inflectional patterns, and are typical of many Eastern as well as Southern Nilotic languages (Dimmendaal, 1983c). Verbs may take a range of possible prefixes, for functions such as person-marking, aspectual marking, and imperative marking, among others, in addition to suffixes relating to functions such as habitual, applicative, and ventive/itive marking. Tone changes also play a role in the verbal morphology (Moodie, in press).

1.4.3.2 Phonology

Slightly more information on Lopit phonology was available at the outset of this project, and has continued to emerge, though findings have varied. A 9–10 vowel system has been proposed for Lopit by Vossen (1982) and Turner (2001), including a contrast on the basis of the phonological feature 'Advanced Tongue Root', or ATR, while Stirtz (2014b) only finds evidence for a 5-vowel system with no ATR contrast. ATR contrasts are commonly noted for African languages (Casali, 2008), but their phonetic implementation is not crosslinguistically well understood, and in particular has received little attention for Nilo-Saharan languages (see 2.3 and 4.2 for further discussion). The Lopit consonant inventory, according to existing work, includes at least voiced and voiceless stops at four supralaryngeal places of articulation, and corresponding nasals (Vossen, 1982; Turner, 2001; Stirtz, 2014b); Vossen (1982) and Turner (2001) also note the presence of a word-final glottal stop. 3–4 fricatives are observed, with some speculation about their relationship to particular stops (Vossen, 1982; Turner, 2001). All three authors note that at least some consonant types in Lopit also exhibit a contrast drawing at least partly on length differences, and while there is some variation in which segments this is proposed for, and whether or not such contrasts are found word-initially, all include observations of the typologically uncommon length differences among palatal and labial-velar glides. While similar observations of distinctions based on length (or strength - see 2.2.4 and 5.2) have been made for some related Eastern Nilotic languages, these types of glide contrasts have not yet received phonetic attention for Nilotic languages, and indeed very little crosslinguistically. Observations on Lopit tonal phenomena, discussed further in

2.4 and 6.2, suggest that tone likely has a significant grammatical role in addition to a more limited lexical role (Vossen, 1982; Turner, 2001; Stirtz, 2014b), as has been widely noted for Nilo-Saharan languages; given the descriptive challenge this poses, it is not surprising that comprehensive phonological and morphosyntactic studies of Nilo-Saharan tone systems remain limited, and phonetic studies even more so. For Lopit, 3–4 tones have been suggested, including either High, Low, Mid and Falling (Vossen, 1982), High, Low, and Falling (Turner, 2001), or High, Low, Falling and Rising (Stirtz, 2014b).

1.4.3.3 Dialect differences

There are various indications of linguistic differences across the Lopit dialect areas. For example, data from the sources discussed above, as well as Ladu, Nartisio, Bong, Odingo and Gilbert (2014b) and that collected in the present study, suggest the possibility that speakers of different dialects use different tonal patterns for lexical items which are segmentally the same. While the dialects appear to draw on more or less the same segmental inventory (though the varied findings of different studies, e.g. regarding the vowel inventory, may also be related to dialect differences), there is also evidence of of segmental alternation across lexical items in different dialects. Stirtz (2014b, pp. 23–24) specifically investigates this, based on comparisons of the forms for the 285 nouns in singular and plural form, and 60 imperative verbs, and finds that across all five dialects studied (Ngabori was not represented), only 30.2% of the words are segmentally identical. The Dorik dialect, which is the focus of this study, is found to be most similar to Ngutira (62.2%), followed by Lohutok (49.1%), then Lomiaha (48.7%), and least similar to Lolongo (41.7%). Though over 90% of words are lexically similar across the five dialects in these comparisons, there are also lexical differences between the dialects, including for pronouns (Ladu, Nartisio, Bong, Odingo & Gilbert, 2014b). Dialectal variation is also apparent in number-marking, morphophonological processes, forms of prefixes, prepositions and demonstratives, case-marking, and other morphosyntactic patterns (Stirtz, 2014b; Ladu, Nartisio, Bong, Odingo & Gilbert, 2014b; Moodie, in progress). Across all the dialects, the existing segmental and tonal observations have much in common with findings for the non-Bari Eastern Nilotic languages, as will be seen in the overview in Chapter 2.

1.5 Research Motivations, Aims and Scope

1.5.1 Motivations for this study

There are three broad and overlapping motivations for this study, drawn from some of the points raised in this chapter, and further elucidated through the discussion of relevant literature in Chapter 2, and background sections of Chapter 4, Chapter 5 and Chapter 6.

1. There is a paucity of phonetic data for African languages compared to those of other regions, despite the significant influence of African languages on phonological theory. Phonetic data are crucial for testing proposed contrasts and processes, and informs theoretical development.

In general, phonetic data of any sort remains extremely limited for African languages. The seminal work of Ladefoged (1964) on the acoustic and articulatory patterns of West African languages has demonstrated the valuable insights such data offers, as did later studies by colleagues, including studies of some Nilotic languages (e.g. Lindau, Jacobson & Ladefoged, 1972; Jacobson, 1978). More recent research, also including studies of Nilotic languages, has further underscored the scholarly value offered by instrumental analyses of African phonologies (e.g. Guion, Post & Payne, 2004; Edmondson & Esling, 2006; Remijsen, 2013; Remijsen & Ayoker, 2014). Despite this, and wider calls for phonetic research to include representation from a greater diversity of languages (e.g. Ladefoged & Maddieson, 1996a), African languages remain under-represented in the phonetic literature. Pulleyblank and Allen (2013) observe, based on an informal survey of published articles, that instrumental phonetic techniques are under-utilised in studies of African languages, despite the relative availability of suitable tools for phonetic data collection and analysis. They call for an increase in phonetic research on African languages, arguing that phonetic data are key to understanding the sorts of complex phonological phenomena found on the African continent, and in turn, their influence on phonological theory. Examples are given to illustrate the ways in which phonetic data are crucial for verifying audible distinctions, ascertaining the nature of perceptually difficult distinctions, and accessing gestural differences which may be inaudible. Pulleyblank and Allen (2013, p. 14) argue that "[w]ith an increasing emphasis placed on using details of phonetics to supplement phonological theory, there has never been a more pressing need to ascertain the validity and specific nature of theoretical principles at play in the interface between phonology and phonetics". Beyond offering quantitative evidence for phonological contrasts and processes, detailed synchronic studies of the phonetic properties of sound systems in African languages crucially pave the way for further work in areas such as sociophonetics, sound change, language technology, and other fields which would benefit from greater inclusion of under-studied languages (Besacier, Barnard, Karpov & Schultz, 2014; Stanford, 2016).

2. Some features of particular typological interest are found in Nilotic languages, but have in most cases not been subject to the detailed investigations required to make meaningful contributions to crosslinguistic understandings of such features.

The small amount of existing research on Lopit phonology (Vossen, 1982; Turner, 2001; Stirtz, 2014b) points towards the presence of a number of features which are of particular typological interest, but which have not been the subject of phonetic investigations in Lopit, and have in general received limited phonetic attention crosslinguistically. In addition to a wider need for more phonetic data pertaining to African languages, as stated above, there is a need for more research closely examining the acoustic, articulatory and perceptual correlates of phenomena which have been particularly subject to debate, speculation, and varying analyses in individual descriptions of languages around the world and typological overviews. For example, the phonetic implementation of 'Advanced Tongue Root' distinctions, which have been proposed for Lopit and related languages, has been a topic of contention in the phonological literature, informed by empirical data for only a small sample of the many languages which are attested to draw on such contrasts in the vowel system (Gick, Pulleyblank, Campbell & Mutaka, 2006, pp. 2–3; Casali, 2008, p. 536). Much descriptive energy has focused on Niger-Congo languages, and it is not yet clear whether canonical understandings of the phenomenon are as well-suited to Nilo-Saharan languages, or language groupings elsewhere (e.g. Jacobson, 1978). Existing literature on Lopit and related languages also suggests the presence of a length (or in some cases strength) contrast among glides, which is quite uncommon in the languages of the world (Maddieson, 2008), perhaps due to the perceptual challenge such a contrast is expected to pose (Kawahara, 2007). However, there is very little phonetic data available to inform the understanding of how such contrasts are produced, let alone perceived. Lopit and related languages are also all described as exhibiting a number of tonal contrasts, a well-known characteristic of many African languages for which the phonetic literature is also scarce, compared to the phonological studies of African tone systems, or to phonetic analyses of tone systems in regions such as Southeast Asia. Existing experimental phonetic studies have provided evidence for tone systems in some branches of Nilotic that are quite different to the types of tone systems typically proposed for African languages, including characteristics not previous attested to be a salient parameter for tonal distinctions in general (Remijsen & Ayoker, 2014). Phonetic data for Lopit therefore provide the opportunity to develop typological understandings of segmental and tonal phenomena in the Nilo-Saharan phylum and beyond.

3. The understanding of genetic and areal relationships between Nilo-Saharan languages is hampered by limited linguistic data for many of them, particularly minority languages; for some, data collection opportunities may become increasingly limited due to the various socio-political pressures affecting language transmission.

Although the genetic relationships between the Nilotic languages are rather well-understood in comparison to some branches of Nilo-Saharan, many of the languages are vastly under-documented, including those within the Lotuxo sub-family of Eastern Nilotic. Understandings of language evolution and the areal diffusion of linguistic features is, for Nilotic languages and other language families, sometimes based on short wordlists, often with preliminary transcriptions, which limits the possibilities for understanding the connections between different languages, and the changes they have undergone (Vossen, 1982). There is a need for more comprehensive morphosyntactic, lexical, phonological and phonetic data to be collected across languages to inform the wider picture of linguistic relationships and develop more nuanced understandings of local similarities and differences (Dimmendaal, 1988), and as noted by Sands (2009), Africa's least well-documented languages may often be those which have the greatest ability to shed light on African linguistic prehistory. Specifically with regard to phonetic data, more detailed and crosslinguistically representative findings will contribute valuable insights towards an understanding of how particular types of segmental and tonal distinctions have developed, such as the proposed length or strength contrasts among glides in many Eastern Nilotic languages. Furthermore, more findings of this sort will develop the understanding of the range of phonetic implementations found across languages for phonologically similar sounds. A comprehensive understanding of the phonetic correlates of phonemic distinctions can be considered essential to describing the sound system of a language, given that the fine phonetic detail which is crucial to such distinctions cannot be adequately captured using phonetic symbols alone (Ladefoged, 2003b). The need to document linguistic phenomena across Nilotic languages and others in the East African region is all the more pressing given that many languages in this area are minority or marginalised languages. Many are vulnerable due to social, political and economic factors affecting minority communities, particularly in areas where political unrest has been rife for a long time, and some are reportedly in the midst of, or likely susceptible to, processes of language shift (Batibo, 2005; Sands, 2017). As both Batibo (2005) and Sands (2017) emphasise, the vitality of individual languages and the rate at which language shift may occur has likely been vastly underestimated for many languages of Africa, and the need to devote greater attention to recording their structures should be considered urgent.

1.5.2 Aims and research questions

The current project addresses the need for more detailed phonological and experimental phonetic analyses of the sound systems of Nilo-Saharan languages, and the typological characteristics they exhibit, through a focused investigation of the phonetics and phonology of one Eastern Nilotic language, Lopit. The primary aim of this project is to produce a phonetically-based description of the phonology of Lopit, by first developing hypotheses about the segmental and tonal inventory of Lopit based on collected lexical and morphosyntactic data, then using instrumental approaches to test the evidence for three phenomena of particular typological interest: ‘Advanced Tongue Root’ contrasts among vowels, length contrasts among glides, and tonal contrasts. The research project is guided by a series of research questions, beginning with one general question and followed by four more specific questions:

1. What are the major phonological contrasts in Lopit?
2. What are the acoustic correlates of vowel contrasts found in Lopit?
3. What sorts of articulatory mechanisms are involved in producing Lopit vowel contrasts?
4. What are the phonetic characteristics of contrastive glides in Lopit?
5. What are the phonetic characteristics of lexically contrastive tones on nouns in Lopit?

These are addressed in more detail in 2.5, with a discussion of how each question has arisen from available information on the sound systems of Lopit and other Nilotic languages, and crosslinguistic understandings of the phonetics of particular segmental and tonal phenomena. The first research question (henceforth RQ1) is the main focus of analyses in Chapter 3, the second and third (RQ2 and RQ3) are addressed with two experiments presented in Chapter 4, the fourth (RQ4) is investigated in Chapter 5, and the fifth (RQ5) in Chapter 6. Specific hypotheses are also presented in each of the three experimental chapters.

1.5.3 Scope of this project

The focus of this project is on establishing the basic segmental and tonal contrasts in Lopit via phonological analyses supplemented by experimental phonetic analyses of selected phenomena, and as such, to lay the groundwork for further work on the sound system of Lopit. However, limits of both time and available lexical and morphosyntactic data mean that it has not been possible to test the phonetic evidence for all phonemic contrasts in Lopit, and in particular there is much room to expand on the understanding of tone production as grammatical understandings continue to develop. Furthermore, the analyses presented in this study are most representative of the Dorik variety of Lopit; dialectal variation is not explored in any detail, though there are hints that there are a number of interesting possible differences. Other sources of sociophonetic variation are similarly beyond the scope of this study, but this is also an area in which there is much potential for future work. While it is hoped that the detailed synchronic data data presented here will provide a useful contribution to discussions of diachronic processes in the Eastern Nilotic family, which for Lopit have so far been informed by a single wordlist, engagement with historical patterns of change is limited to occasional speculation. Based on the findings arising in the course of this work, some suggestions for fruitful future directions are noted in Chapter 7.

1.6 Methodological Overview

1.6.1 Participants

The primary participants in this study are Lopit speakers living in the south-eastern suburbs of Melbourne, Australia. They are affiliated with the Lopit Community Association of Australia (LCAA), a Melbourne-based community of 10-12 families whose members range in age from very young children to adults in their 50s. To the community's knowledge they are the only Lopit people present in Australia. Members of Melbourne's Lopit community arrived in Australia from 2000, during a time of rapid increase in Sudanese migration to Australia. This has resulted in dozens of Sudanese languages, many of them vastly underdescribed, being represented in Australia (e.g. Musgrave & Hajek, 2010, and as discussed further in 1.6.2.1). Members of the Lopit community have had a range of experiences in different countries before arriving in Australia, but have most commonly spent time in either Kenya or Egypt in between leaving what is now South Sudan and travelling overseas. Partly for these reasons, and as mentioned in 1.3.3, Lopit people have various linguistic resources to draw on. For those living in Melbourne who participated in this study, Lopit is the main language used at home, and other languages used frequently are English and Juba Arabic. These have been learnt at different times; in general, the men report acquiring knowledge of English, Juba Arabic, and occasionally other Arabic varieties prior to arriving in Australia, via some experience with formal schooling (except in the case of Juba Arabic), while the women report developing most knowledge of these languages after arriving in Australia, and have more variable levels of experience with English. It is worth noting that Juba Arabic is a lingua franca among the wider Sudanese community in Melbourne, and that other Sudanese women in addition to the Lopit women involved in this study report the necessity of acquiring Juba Arabic after arriving in Australia.

The Lopit speakers living in Melbourne represent five of the six different dialects mentioned in 1.4, and the data collection and descriptive work outlined in 1.6.2 and focused on in Chapter 3 (relating to RQ1) is based on work with thirteen speakers representing multiple dialects. While the dialects are all reported to be mutually intelligible, it became apparent in the early stages of this project that the differences between dialects can be quite substantial, and include not just variant pronunciations for the same lexical item, but also the use of different lexical items, and some evidence for grammatical variation, as noted above in 1.4.1, 1.4.3, and in work by Stirtz (2014b) and Ladu, Nartisio, Bong, Odingo and Gilbert (2014b). Given this, combined with the experimental approaches required for four of the five research questions listed earlier and discussed in detail in 2.5, a focus on one dialect was best suited to the aims of this project. As such, except where otherwise noted, observations on Lopit phonetics and phonology presented in this work pertain to the Dorik dialect, one of the two northenmost dialects of the language (shown in Figure 1.2). Participants in the phonetic experiments outlined in 1.6.3 were therefore recruited based on both dialect and availability. Six speakers of Dorik Lopit participated in this stage of the research, including four men in the acoustic phonetic experiment discussed in Chapter 4 (for RQ2), two of whom also participated in the articulatory phonetic experiment (for RQ3) discussed in the same chapter; three men and two women in the experiment discussed in Chapter 5 (relating to RQ4), and three men in the experiment discussed in Chapter 6 (relating to RQ5). While the small number of speakers limits the generalisability of the results, the detailed knowledge of their usage patterns acquired in the course of this study provides good evidence of a shared system, and a strong foundation from which later larger-scale work can proceed. In addition, there was some consultation of audiovisual materials recorded by Lopit community members during visits to South Sudan, and by Moodie (in progress) in Kakuma Refugee Camp in Kenya.

1.6.2 Approaches to language documentation

1.6.2.1 Ex-situ language documentation

As noted, the data collection for this study falls into two broad, but overlapping stages. The initial stage draws on language documentation approaches (e.g. Woodbury, 2003; Himmelmann, 2006), focusing on collecting a range of data types to contribute to a record of the Lopit language, and to inform the description of phonological, lexical and morphosyntactic patterns. Ongoing work investigating Lopit morphosyntax is being undertaken by Moodie (in progress); for the present study, the collection of data allowing for detailed phonological observations is a particular focus. This then enables a second stage, also descriptive but focused on using quantitative phonetic methods to test specific hypotheses about the sound system in Lopit. Both stages involve fieldwork in Melbourne with the diaspora community of Lopit speakers introduced above. An Australian city is not a canonical example of a fieldsite for research on an under-described African language, and given this, it is worth providing some explanation of why this approach is justified, and the value that contributions made in the course of this work may have.

A typical (and preferable) approach to describing and documenting a language is to work with speakers living in the area in which a language is traditionally spoken. Many authors have written about why this is the ideal situation, and common themes that emerge are that this is the natural geographic and cultural setting in which the language is used in daily life, that speakers in this location will have experienced minimal language contact, and that there will be an availability of many speakers of the language, offering a wide choice of language informants (e.g. Crowley, 2007; Aikhenvald, 2007; Hyman, 2001a). Alternatives to this sort of in-situ work are discouraged, as discussed further below. However, in some cases, it may be extremely difficult to engage in linguistic research in the area where a given language is traditionally spoken, either as a visiting fieldworker or a community linguist. Political instability, high levels of violence and serious challenges to population health may render a location both dangerous and difficult to access for external researchers, and create much more pressing concerns for those living in the area.

The former Sudan offers one such example. Between the First Sudanese Civil War, from 1955-1972, and the Second Sudanese Civil War, from 1983-2005, an estimated 2.5 million people died, 1 million became refugees or were externally displaced, and a further 5 million people were internally displaced. The vast majority of deaths were civilians, suffering famine and disease during the protracted fighting and disruption (LeRiche & Arnold, 2013). The 2005 signing of the Comprehensive Peace Agreement between the southern-based Sudan People's Liberation Movement (SPLM) and the northern-based Government of Sudan was followed in 2011 by a referendum in which residents of southern Sudan voted overwhelmingly to secede, resulting in the emergence of The Republic of South Sudan as an independent country on July 9th, 2011. However, fighting within South Sudan gradually escalated as a result of internal political tensions, and civil war again broke out in December 2013. The South Sudanese Civil War has so far resulted in tens of thousands more deaths and the displacement of 1.7 million people internally and 1.2 million externally (UNHCR, 2016), and lack of access to food, sanitation, medical treatment, and basic services has continued to affect the daily lives and livelihoods of those in the country. The human cost of 60 years of near-perpetual warfare in the region is enormous and ongoing, and cannot be understated. Against this backdrop, it is not surprising that the opportunities to further research on Sudanese languages and cultures have been, and continue to be, extremely limited.

However, many speakers of minority languages from conflict zones in Africa now live outside their homeland, having fled during wartime to seek refuge in other countries. Tens of thousands of Sudanese people live in refugee camps in Kenya and Uganda, and many have travelled, often via those camps, to other countries throughout Africa and overseas, including Australia. In Australia, recent decades have seen a significant increase in migration from Africa, with the rise from 111,831 to 311,199 people of African origin recorded in the 1991 compared to the 2011 census representing a 178% increase (Musgrave & Hajek, 2015). These arrivals from Africa include many people born in the former Sudan. In the 2011 Australian census, a total of 22,856 people reported their country of birth as Sudan or South Sudan, and there are likely many more who identify as Sudanese but were born in other countries such as Kenya. The state of Victoria is home to the largest number of Sudanese-born or South Sudanese-born people (7,203), followed by New South Wales (6,190) (DIAC, 2014b, 2014a). Australia's Sudanese communities encompass ethnic and linguistic diversity reflective of that found in the former Sudan; in a survey of Melbourne's wider Sudanese community, over 40 Sudanese languages are found to have a speaker presence in Melbourne, and typically these languages are one option among several for the highly multilingual community members (Musgrave & Hajek, 2010, 2013). Sudanese languages reported to have users in Melbourne include a number of minority languages for which the linguistic record is very limited. The diversity of Sudanese languages being spoken in urban Australian contexts offers much potential for fruitful engagement between linguists and speakers of this languages (Musgrave & Hajek, 2015), particularly while Sudan and South Sudan remain challenging and often inacessible sites for linguistic fieldwork.

There are differing opinions on the value of linguistic research with speakers living away from their traditional homeland, referred to as urban fieldwork, diaspora documentation or ex-situ fieldwork. In some views, linguistic research in such locations does not sufficiently meet the criteria to be considered fieldwork; for example, Hyman (2001a) lists distance (from the researcher's home or university), 'exoticism' (relative to one's own language), and duration as three prototypical features of fieldwork, and suggests that work for example on an African language with speakers near a researcher in California is better considered 'informant' work rather than 'fieldwork', being both too close to home and assumed to likely be of only limited duration. In Crowley's (2007) view, any research work with a speaker of another language can be legitimately be referred to as fieldwork, but linguistic work with speakers of another language living in the suburbs of a large urban centre is likely to at best be useful for studying a particular linguistic feature, rather than producing a comprehensive account of a language. Much of his concern stems from an assumption that descriptive work in ex-situ contexts will be based on data collected with a single speaker, and without the opportunity to observe natural interactions between speakers. Opposition towards ex-situ fieldwork is expressed particularly strongly by Aikhenvald (2007), who views it as falling under 'interview' fieldwork in a dichotomy between this and 'immersion' fieldwork, and considers it to be highly undesirable for the purposes of linguistic description, similarly assuming limited opportunities to work with multiple speakers and also particularly apprehensive about the possible extent of contact-induced language change in migrant communities. She suggests that work with diaspora communities in urban settings is "bound to give a skewed picture of the language's structure" (2007, p. 5), and recommends that in cases where the preferred fieldsite cannot be visited due to war or other political problems, research on the language should be set aside until such time as the political situation improves, in favour of immersion fieldwork focusing on a different, more accessible language.

Other scholars argue that, in fact, we cannot wait. Kaufman (2009), a founder of the Endangered Language Alliance in New York City, argues that the looming loss of so many of the world's languages makes ex-situ documentation increasingly important, and that to bypass work with migrant speakers in diverse cities is to overlook an enormous resource. Henderson (2015) reiterates that the reason some diaspora communities exist is because of forced displacement during war, and observes that while the real impact of war on language loss is unknown, it has likely been underestimated. He highlights Africa, and regions such as the former Sudan, as particular examples with both high levels of linguistic diversity and high levels of population displacement. Sands (2009, p. 561) observes that within Africa, "(l)anguages used by current or former residents of conflict zones and hunter-gatherers are among the most underdocumented languages on the continent", and notes that the lack of documentation is especially serious for languages in southwestern Ethiopia, South Sudan, northeastern Nigeria, Chad, and Cameroon. Williams and Comfort (2007, p. 263) state simply that "(g)iven the current state of language obsolescence, it would be a tragedy not to begin documenting endangered languages among displaced persons". In diaspora communities, there may also be particular enthusiasm for contributing to the linguistic record of a language, especially where a language is closely tied to ethnocultural identity (Musgrave & Hajek, 2013, 2015).

Furthermore, a number of authors argue that while there are certainly differences in the extent to which ex-situ language documentation can capture the full range of linguistic patterns and behaviours used by speakers of a language, some of the disadvantages, or impedances, to linguistic research in such contexts have perhaps been overstated (while perhaps also overstating what can be accomplished within a typical in-situ language documentation project). For example, warnings against ex-situ documentation, such as Aikhenvald's, give little recognition to the potential strength of language maintenance in migrant communities in large urban centres such as London; these settings often include robust and cohesive communities of speakers whose traditional language is used in daily life, and, depending on the age of community members, may include surprising numbers of monolingual speakers (Henderson, 2015; Austin, 2007). Within such communities there may be many speakers available to engage in language work over an extended project, and the effects of contact-induced language change may therefore not be as swift nor as extensive as some authors assume. At the same time, multilingualism and cross-language influences are not factors exclusive to migrant communities. As Bowern (2010, p. 340) notes, while fieldwork focused on individual languages has tended to view multilingualism as a problem, and perhaps " a source of contamination of the data under consideration", it is a linguistic reality; few communities are wholly linguistically homogeneous and completely isolated from their neighbours. Indeed, this is likely particularly true of minority languages which are the focus of in-situ documentary efforts. Henderson (2015) notes that most minority languages are under pressure from larger regional lingua francas, and that for small languages, situations of contact-induced change are likely the norm rather than the exception. There may therefore be some qualitative similarities in the contact situations affecting languages in-situ and ex-situ. However, stable multilingualism may also be characteristic of many communities, including in many parts of Africa (Lüpke, 2015).

A recurring theme in discussions on this topic (including informal discussions, e.g. as summarised by Gawne, 2012; Tsutsui, 2015) is the notion of 'authenticity' in the context of language documentation, or as Henderson (2015, p. 245) puts it, "the underlying assumption that the language spoken in the home country is in some way more pure, uncontaminated or otherwise legitimate for documentation efforts". Henderson (2015,

p. 246) cautions against this bias, observing that it brings us "dangerously close to falling into the trap of believing that any language documentation effort ever really documents anything we commonly refer to as 'a language' ". He emphasises that while languages are typically spoken about as though they are entities which are easily isolated, quantified and labeled, they are "dynamic social systems made up of the collective consistencies and variation in the idiolects of the people who speak them", and that accordingly, all any language documentation project does is document the linguistic behaviour of particular speakers in particular contexts. The diaspora is one such context. A number of diaspora documentation projects have taken or are currently taking place, for example on Ghulfan, a Nilo-Saharan language of Sudan, with speakers living in Egypt (Williams & Comfort, 2007), and on Moro, a Niger-Congo language of Sudan, with speakers living in the United States (Rose, 2011). Chimiini, a Niger-Congo language of Somalia, has been studied with speakers living in Atlanta, London and Mombasa (Henderson, 2015), and Luwo, a Nilo-Saharan language of South Sudan, has been the subject of recent linguistic work, with a specifically anthropological focus, undertaken with displaced speakers in Sudan (Storch, 2014). Research has been undertaken with speakers of various minority languages living in New York City (Kaufman, 2009), and it is worth noting that there are many other examples of linguistic research undertaken in ex-situ contexts which are not explicitly framed that way. These studies have all made significant contributions to the linguistic record of under-studied languages, and show that careful and valuable linguistic research can successfully be carried out in diaspora settings, providing a further motivation for the current study.

1.6.2.2 Data collection, database and phonological analyses

Bearing these issues in mind, the general approach to this project was to contribute to the linguistic record of Lopit by working closely with various members of the Lopit community in Melbourne over an extended period of time, and collecting a range of data types reflective of their linguistic behaviour. Data was collected with a view to enabling observations of the phonological, lexical, and morphosyntactic patterns shared by these speakers, with consideration of the sociocultural and linguistic background of individual speakers and the project itself. The phonological patterns are, of course, a particular interest for this project, and further methodological detail pertaining to this first stage of fieldwork precedes the phonological analyses presented in Chapter 3. Regular data-collection sessions took place, sometimes with groups or pairs of speakers, but for the most part with individual speakers. These were held at different locations, typically in homes in Melbourne's south-east. In addition to research-focused recordings and discussions, many informal discussions in and about the Lopit language, and about Lopit culture, took place during time spent with community members, their families, and friends in the wider Sudanese community.

Given that the linguistic record of Lopit was very limited at the outset of this project, as described in 1.4.2, this project began with a large amount of lexical data collection, such as the elicitation of core vocabulary and common words and expressions, and comparative elicitation of Lopit vocabulary presented in other sources. Further lexical elicitation was guided by particular themes, such as bird species, wild foods, and traditional dancing, and this was complemented by the collection of various texts, for example procedural descriptions of drum-making, traditional stories, and other narratives. These are discussed further in 3.2.2. Though data collection on these topics took place away from the traditional sites of these activities and relevant settings, the sessions benefited from various materials used as stimuli for discussion, for example reference books of plant and animal species of the East Africa region, and large numbers of photographs and videos taken by community members during return visits to their home villages in South Sudan. These videos include some narrative and conversational content, which, though it has not formed the basis of analyses presented here, allowed for some general comparisons of patterns. Some reference has also been made to audio and video-recorded narrative, song and conversational material collected by Jonathan Moodie with members of the Lopit community in Kakuma Refugee Camp in Kenya, as well as to written materials sent through in ongoing communication with members of that community.

Lexical data emerging from recording sessions in Melbourne was added to a lexical database, to enable searching across a number of parameters including the segmental and tonal content of a word, as well as its CV structure. The relevant software and procedures are discussed in 3.2.3. Emerging phonological and morphological patterns were queried in accompanying discussion, and explored and tested further in targeted elicitation using a range of construction types. Sections of these have been transcribed, as well as selected narratives. As data accumulated during this initial stage of the project, the research questions listed in 1.5.2 were borne in mind. In particular, data that would allow RQ1 to be appropriately addressed were sought out.The analyses presented in Chapter 3 are accompanied by several hundred examples, with references to the audio recording from which is example is drawn. Glosses are accompanied by basic grammatical information, to the extent that it is currently understood. In addition to insights from the data collected directly as part of this project, the understanding of Lopit phonology and particularly morphosyntax has also been informed by data from the 2011 field methods class discussed in 1.4.2, and most substantially by ongoing research by Moodie (2012, in progress), also a contributor to the lexical database and the wider documentation project. While a reasonable understanding of the derivational and inflectional patterns affecting nouns, including grammatical uses of tone, has developed over the course of this Melbourne-based documentation project, Lopit verbal morphology has presented some particular challenges, particularly regarding tone, which are still being explored (Moodie, in press). These are noted where relevant in the following chapters. These unresolved questions have implications for the ability to control for grammatical tone, so while phonological analyses draw on a range of data types, experimental work discussed below in and in later chapters draws substantially on nominal data.

1.6.3 Quantitative investigations

1.6.3.1 Laboratory phonology and linguistic phonetic fieldwork

The phonetic investigations which build on the work described above are informed by the approaches of laboratory phonology, a term coined by Pierrehumbert in 1987 in advance of the first workshop bearing that name. While many of the motivations, models and methodologies which can be captured under this label were not in themselves new, the name recognised the need for, and move towards, hybrid methodologies to bridge the gap between phonetics and phonology for the mutual benefit of both disciplines (Beckman & Kingston, 1990). A particular motivation was the need to undo the assumed division of labour between phonologists and speech scientists which "creates the harmful illusion that we can compartmentalize phonological facts from phonetic facts" (Beckman & Kingston, 1990, p. 5), and to pursue an understanding of language sound structure that is informed by both discrete and continuous perspectives (Pierrehumbert, Beckman & Ladd, 2000). As an ultimately multidisciplinary endeavour, a general goal of research in the laboratory phonology community is to bring systematic experimental methods to bear on questions of human speech sounds and sound systems (Cohn, 2010; Cohn, Fougeron & Huffman, 2012). In reviewing the trajectory of this enterprise over two decades, Cohn (2010, p. 7) notes that the emphasis on experimental data has highlighted the ways that relying on impressionistic data is inadequate, and showed that greater attention to fine detail in empirical work better enables the development of adequate models. Cohn (2010) also observes that research in laboratory phonology has encouraged the idea that the base of empirical knowledge needs to be strengthened through both experimental work as well as fieldwork pursuing cross-language documentation. She draws connections between this and the long tradition of linguistic phonetics, as well as recent initiatives emphasising the need for greater documentation of minority and endangered languages, as discussed above in 1.6.2.1.

Research in the area of linguistic phonetics has offered significant insights into the production strategies used to create distinctions between speech sounds in many languages around the world, including a number of African languages (e.g. Ladefoged, 1964), but the number of languages for which extensive phonetic descriptions exist remains small (Ladefoged, 1997). The view that the empirical base of phonetic knowledge needs to be improved by linguistic phonetic work representing a greater diversity of languages, particularly endangered and minority languages, is widely echoed (Ladefoged & Maddieson, 1996a; Ladefoged, 1997; Maddieson, 2002; Gordon, 2003; Bhaskararao, 2004). However, as Maddieson (2002) observes, amidst the renewed interest in documenting endangered languages and furthering typological studies with more crosslinguistically representative data, both phonological and particularly phonetic analyses have been given short shrift. Reviewing a small sample of recent grammatical descriptions of languages, he finds that in general, very little space is devoted to description of sound systems, and that the descriptions often lack examples demonstrating phonological contrast or clear descriptions of segmental realisations, let alone hard evidence documenting the phonetic facts in the way that example sentences are used to illustrate syntactic patterns. He argues that, given that the phonetic properties of a language are the foundation for non-arbitrary patterns in its phonology, and higher-level structures, "explicit phonetic documentation should be a basic part of any grammar which aims to give a general description of a language" (Maddieson, 2002, p. 415). While it is arguable whether phonetic documentation needs to be included in 'the grammar', rather than as a separate body of work emerging in tandem, there is clearly value in giving greater attention to the phonetic facts in describing a language's sound system.

In particular, it has been emphasised by various authors that while the International Phonetic Alphabet provides an extremely useful tool for transcribing language data, it necessarily uses symbols to represent discrete categories, whereas speech sounds, as theoretical entities which can be equated across languages, are the continuous dimensions of articulation and perception (Pierrehumbert et al., 2000; Ladefoged, 2003b), and "[l]anguages differ in how they bundle and divide the space made available by these dimensions" (Pierrehumbert et al., 2000, p. 10). Maddieson (2002, pp. 417–418) highlights quantity contrasts and tonal distinctions, both of particular interest in this study, as examples where the range of language-specific implementations clearly demonstrate the gradient nature of linguistically salient distinctions; languages vary in the duration ratio of long to short consonants, as well as in the relationship between consonant length and the duration of preceding vowels, and in the suprasegmental phonology, the alignment of tonal targets also varies across languages. In addition, many linguistic descriptions draw on idiosyncratic, imprecise or ambiguous uses of IPA symbols, and other types of descriptive labels. Maddieson (2002, p. 416) lists the use of the terms 'fortis/lenis' and labels such as 'Advanced Tongue Root' (both also of particular relevance to this study) as canonical examples of this problem; these terms have been used in many and diverse ways in the literature, and neither gives sufficient information about the acoustic and articulatory properties intended to be conveyed. Furthermore, as Ladefoged (2003b) notes, the concept of what it means to 'describe a language' has evolved; language and speech are recognised as sets of behaviours shared, to some extent, by groups of speakers, and understanding the permissible variation is an important part of understanding the system.

However, as often pointed out by Ladefoged and colleagues, while comprehensive phonological description requires attendant phonetic analysis, meaningful phonetic analysis also requires some initial understanding of the phonological patterns of a language, leading to a chicken and egg problem (Ladefoged, 1997; Maddieson, 2002; Ladefoged, 2003b, 2003a). While it is often the case that for a given language, there are existing lexical or phonological materials available for a phonetician to consult, there is also the potential for existing materials to be based on a different dialect, have been captured before the spread of particular sound changes, or to include the types of ambiguities, unclarities, idiosyncrasies or errors noted above. Practically, then, the phonological and phonetic analyses must proceed hand-in hand, with quantitative results contributing to a potentially evolving phonological understanding (Ladefoged, 2003a, p. 1). It is work of this sort that Pulleyblank and Allen (2013) advocate for more of in research on African languages. Good examples of this approach can be found among recent instrumental studies of Nilotic languages, in cases where existing descriptions have informed the research, but the phonetic evidence has in turn led to revised understandings of the nature and inventory of contrasts (e.g. Remijsen, 2013; Remijsen & Ayoker, 2014; Edmondson & Esling, 2006).

1.6.3.2 Experimental data and analyses

In the spirit of the general approaches discussed above, a number of experiments were designed for quantitative investigations of selected aspects of Lopit phonology. These experiments relate to Research Questions 2-5, as listed earlier and discussed in detail in 2.5. For each of these research questions, specific hypotheses were developed based on observations made in Chapter 3 and drawing on data collected as outlined there and in 1.6.2 (relating to RQ1). The hypotheses are also informed by the wider literature on the sound systems of Nilotic languages, of which an overview is given in the following chapter, Chapter 2, and the crosslinguistic phonetic literature pertaining to the phenomena of interest, which is summarised in the background section of each experimental chapter (4.2, 5.2, 6.2). The hypotheses are listed in each of the three experimental chapters. Speakers of the Dorik dialect of Lopit participated in these quantitative studies, as noted above. Chapter 4 focuses on the acoustic and articulatory investigations of Lopit monophthongs, relating to RQ2 and RQ3; Chapter 5 focuses on the investigation of Lopit glides, relating to RQ4, and Chapter 6 focuses on lexical tone, relating to RQ5.

These investigations require targeted approaches, and the methodological approach used in each experiment is addressed in detail in the relevant chapter (4.4, 4.6, 5.4, 6.4). Very broadly, however, some methodological aspects are shared. To test the hypotheses relating to each of the four quantitatively-oriented research questions, wordlists were compiled to be used as stimuli, drawing on data from the lexical database discussed in 1.6.2. While it is difficult to construct tightly controlled experimental datasets at this relatively early stage in the documentation of Lopit, the wordlists were constructed to be as suitable as possible given the available lexical and morphosyntactic data and the specific hypotheses for each study. Audio recordings of selected lexical items being produced were collected to address RQ2, RQ3, RQ4 and RQ5, and for RQ3, video data was also collected during ultrasound tongue imaging. The data were segmented and labelled according to standard conventions, and acoustic and articulatory data were extracted and analysed using established tools and techniques, as discussed in later sections. While many aspects of Lopit phonology have emerged as potentially interesting targets of phonetic exploration over the course of this thesis, the instrumental analyses presented here are primarily focused on establishing the quantitative evidence for specific phonological contrasts. However, the results presented in each experimental chapter also contribute to wider typological understandings, and raise many possibilities for fruitful avenues of further research in Nilotic and other languages. Together with the specific results of the quantitative analyses, these inform the overall discussion of findings contained in Chapter 7.

1.7 Chapter Summary

This chapter has provided essential background to the research project presented in this thesis. Following an introduction to the Lopit people of South Sudan and their history and culture, the overview of existing research on the Lopit language, of the Eastern Nilotic family, shows that there is much still to be learned about its patterns and structures, including for specific areas of the sound system. Given the level of description for many languages of Africa, this is not uncommon, and the outlined motivations for this study include a desire to contribute more phonetic data to the understanding of African languages, particularly pertaining to typological features of interest, and particularly focusing on languages which have received limited scholarly attention. From these motivations arise the specific aim of this project, to produce a phonetically-based analysis of the phonology of Lopit, and a series of research questions targeting aspects of particular interest in the sound system. An overview of the methodological approach was also presented, introducing the participants in this study, the general approach to language documentation in a diaspora setting, and the perspectives of laboratory phonology and linguistic phonetics which underpin the quantitative analyses. As noted, methodological details are discussed in more depth in later chapters. The following chapter, Chapter 2, provides further background of a different sort. It constitutes an overview of the segmental and tonal phenomena in Nilotic languages, outlining the main phonological patterns and highlighting features of particular interest. These inform the phonological and phonetic analyses of Lopit, which are the focus of subsequent chapters.

Chapter 2

The Phonetics and Phonology of Nilotic Languages

2.1 Introduction

Chapter 1 introduced the Lopit language, and the general approach taken in this project to investigating its sound system. The present chapter provides further necessary background to this work, and forms an overview of the main characteristics of Nilotic sound systems, discussing the phonological and, where possible, phonetic nature of contrasts found in Nilotic languages. Information presented here is intended to give a sense of the general tendencies across the three branches of Nilotic in terms of segmental and tonal inventories, and highlight features of particular interest, while also illustrating that there is much scope to expand on the understanding of Nilotic speech sounds. Previous observations for Lopit and closely-related languages such as Otuho are treated with particular attention, though more detailed discussion of specific observations is also included throughout Chapter 3, and in the following chapters. Generalisations made in this section regarding Eastern, Southern and Western Nilotic languages are based on data available at the time of writing, and it should be borne in mind that at this stage the phonological descriptions of a number of Nilotic languages are based on very limited (and sometimes not easily accessible) data.[1] Historically-oriented discussion of proposed sound changes

[1]Segments discussed in this chapter are generally represented as they are in the original work, but adapted to align with the conventions of the International Phonetic Alphabet where necessary (e.g., palatal glides are represented as /j/ rather than /y/, and consonant length is indicated using the length diacritic rather than doubling the symbol). Where tone categories are discussed, capitalisation indicates the labels used by authors for observed tones, compared to lowercase descriptors of pitch (e.g. 'High' compared to 'high').

and correspondences across languages of the Nilotic family is largely beyond the scope of this chapter, but can be found in Vossen (1982), Rottland (1982), Dimmendaal (1988), B. L. Hall and Hall (1996), and Storch (2005). As noted in Chapter 1, phenomena of particular interest for this study include 'Advanced Tongue Root' contrasts among vowels, phonemic length differences among glides, and tonal distinctions. However, extended discussion of the crosslinguistic and phonetic literature pertaining to each of these phenomena is reserved for each experimental chapter, where it provides the necessary background to the specific hypotheses and methodologies presented there (see 4.2, 5.2, and 6.2). In Chapter 7, I return to a consideration of how aspects of Lopit phonetics and phonology are situated in the Nilotic and wider crosslinguistic context.

In 2.2, Nilotic consonant inventories are discussed, beginning with the place contrasts among stops and nasals (2.2.1), followed by manners of articulation (2.2.1), laryngeal settings and airstream mechanisms (2.2.3), and then length/strength contrasts (2.2.4). An overview of contrasts in Nilotic vowel inventories is found in 2.3, including a brief introduction to 'Advanced Tongue Root' contrasts (2.3.1), a detailed overview of height, backness and rounding contrasts (2.3.2), a summary of key uses of phonation differences (2.3.3), and a discussion of the range of possible vowel length contrasts (2.3.4). I then discuss Nilotic tone systems in 2.4, first briefly addressing some of the functions of tone in Nilotic languages (2.4.1), then turning to an overview of tone levels and basic contrasts (2.4.2). Following some additional discussion of contour tones (2.4.3), I note some further prosodic considerations (2.4.4). In 2.5, the five research questions guiding this project are discussed in relation to areas of specific interest emerging from the overview. Readers familiar with the literature on Nilotic phonological systems will be well-equipped to begin at this section, in advance of the crosslinguistic discussions contained in later experimental chapters.

2.2 Nilotic Consonants

2.2.1 Place of articulation

The number of place distinctions is a key difference across the three branches of the Nilotic language family. Nilotic languages minimally have consonantal contrasts at four supralaryngeal places of articulation: labial, alveolar, palatal/postalveolar and velar. This is most typical of Eastern and Southern Nilotic languages. However, in the Western Nilotic language family, five supralaryngeal places of articulation are usual, with most languages exhibiting a contrast between dental and alveolar consonants. As will be shown, while there appears to be general agreement in terms of the place distinctions used in individual languages, and shared by closely-related languages, many questions remain, particularly relating to the gestural configuration of the active articulator in the production of Nilotic consonants.

Contrasts at five primary places of articulation are observed for varieties of Dinka, Nuer, and for Thok Reel, all languages of the Dinka-Nuer branch of Western Nilotic (Andersen, 1987; Remijsen & Manyang, 2009; Crazzolara, 1933; Faust & Grossman, in press; Yigezu, 1994; Reid, 2010). The same is found for most Western Nilotic languages of the Northern Luo branch, such as Shilluk, Päri, Anuak, Jumjum, and Mayak (Gilley, 1992; Remijsen, Ayoker & Mills, 2011; Andersen, 1988a; Reh, 1996; Andersen, 2004, 1999a). Minor differences are observed for some Northern Luo languages such as Kurmuk (Andersen, 2007), which has no dental nasal, and Belanda Boor, which has additional labial-velar stops (involving simultaneous labial and velar constrictions) (Von Heyking, 2013). For languages of the Southern Luo branch of Western Nilotic, contrasts between dental and alveolar stops are not common; they are not present in Kumam, Lango, or Acholi (Hieda, 2011; Noonan, 1992; Crazzolara, 1955; Hieda, 2016), and are present for stops but not nasals in Alur and Dholuo (Ringe, 1948; Tucker, 1994). Like Belanda Boor, Alur also has labial-velar stops. While not always specified, some descriptions of Western Nilotic languages indicate that the alveolar consonants tend to be apical, involving the tongue tip, while the dental (or explicitly interdental) consonants tend to be laminal, involving the tongue blade. For Dholuo, experimental phonetic results suggest that the (inter)dental stops are likely better characterised as affricates for which production differs in prosodically strong compared to weak positions (Degenshein, 2004).

For the Southern Nilotic languages, consonant inventories with four supralaryngeal place distinctions (labial, alveolar, palatal and velar) for stops and nasals are described for varieties within the Kalenjin group, such as Nandi, Endo, Pökoot and Kipsigis (Creider & Creider, 1989; Zwarts, 2004; Crazzolara, 1978; Baroja, Sikamoy & Partany, 1989; Rottland, 1982; Toweett, 1979). These are also observed for Omotik and Datooga (Rottland, 1982), but for Datooga, a uvular stop has also been proposed (Rottland, 1983). The Eastern Nilotic languages show some differences across the family; within the Bari group, Bari and Mundari have stops and nasals at four primary places of articulation (Spagnolo, 1933; Vossen, 1982; Stirtz, 2014a), but Kuku and Kakwa additionally have labial-velar stops and nasals (Cohen, 2000; Onziga & Gilley, 2012).[2] While labial-velar consonants are found in many African languages, including some Nilotic languages noted above, they are more common among languages of the Niger-Congo phylum and for languages elsewhere in the Nilo-Saharan phylum, particularly those spoken in the Sudanic belt region (Clements & Rialland, 2008). Rather unusually for a Nilotic language, Kakwa has additional retroflex stops, though no retroflex nasal.

Across the non-Bari Eastern Nilotic languages, of which Lopit is one, place of articulation contrasts are very consistent. Labial, alveolar, palatal and velar stops and nasals are proposed for Turkana, Toposa, Karimojong, and Ateso, all of the Teso-Turkana group (Dimmendaal, 1983b; Heine, 1980; M. C. Schröder, 2004; Vossen, 1982; Novelli, 1985; Hilders & Lawrance, 1957; Schrock, 2014; Barasa, 2017). The same four place of articulation contrasts are typical among Maa languages such as Camus and Sampur and the many other Maa varieties which are sometimes collectively referred to as Maasai[3] (Heine, 1980; Vossen, 1982; Tucker & Mpaayei, 1955; Levergood, 1987; D. L. Payne, 2012), and appear to have been used in the closely-related Ongamo (Ngasa) language, which is no longer spoken (Heine & Vossen, 1975; Vossen, 1982). There is some variation across lan-

[2] Some analyses of Bari, such as Hollman, 1992, cited in Stirtz, 2014a, also posit /ɡʷ/ as a single phoneme, and Cohen, 2000, p. 3 notes regular correspondences between this and Kuku /ɡb/.

[3] The term 'Maasai' more properly refers to one particular Maa-speaking ethnic group.

guages and the work of different researchers in whether the anterior coronal consonants are described as alveolar or dental, which may be related to different impressions of the posture of the active articulator. For Kisonga Maa, linguograms and palatograms collected using static palatography reveal an apical articulation for /d/ and /n/, compared to the laminal articulation of the voiced coronal stop and nasal which have been variously described as having a palatal, alveopalatal or postalveolar place of articulation (Epstein & McCrary, 2002). For languages in the immediate Lotuxo family, the same four primary place contrasts are again observed, for example for Otuho (Muratori, 1938; Vossen, 1982; Coates, 1985), Dongotono and Lokoya (Vossen, 1982), and Lopit (Vossen, 1982; Turner, 2001; Stirtz, 2014b). For these languages, additional coronal contrasts based on length (or 'strength') are also proposed, as discussed in more detail in 2.2.4, and differences in the articulatory gesture for geminates compared to singletons are in some cases suggested in accompanying discussion.

Some Western Nilotic languages also feature a marginal glottal consonant, generally only found in word-initial position. In Nuer there is a voiced or voiceless glottal fricative (Frank, 1999; Yigezu, 1994), in Thok Reel, Päri, Anuak, Jumjum and Mayak there is a glottal stop (Reid, 2010; Andersen, 1988a; Reh, 1996; Andersen, 2004, 1999a), and Dholuo and Alur have both a glottal stop and fricative (Ringe, 1948; Dimmendaal, 1995; Heusing, 2006; Tucker, 1994). Among the Eastern Nilotic languages, Bari, Kuku and Mundari also have a glottal stop, which is restricted to word-final position in Bari and Kuku, and to specific morpheme boundaries in Mundari (Spagnolo, 1933; Cohen, 2000; Stirtz, 2014a). For Bari, some instances of the glottal stop may be word-final realisations of other consonants such as /l/ and /d/ (Spagnolo, 1933, p. 7). A rare intervocalic glottal stop is noted for some Maa varieties (D. L. Payne, 2012), while for Ateso, Tucker and Bryan (1966, p. 447) note a word-final glottal stop occurring after some non-devoiced vowels. For Otuho, a word-final glottal stop is observed by Muratori (1938), Tucker and Bryan (1966), Vossen (1982) and Coates (1985), specified by Coates (1985) as only appearing pre-pausally. While Vossen (1982) explicitly states he can find no synchronic or diachronic explanation for it, Coates (1985) speculates that while it appears to be phonemic, there may be a historical relationship between the glottal stop and tone. Vossen (1982) similarly notes the word-final glottal stop in Dongotono, Lokoya and Lopit. For Lopit, though Stirtz (2014b) does not note a glottal stop (though a glottal fricative is proposed, as discussed further in 2.2.2), Turner (2001, pp. 30–39) does, and describes it as "a bit of a mystery"; though, like Coates (1985), he speculates that there may be a relationship between the glottal stop and other segmental or tonal patterns, he finds no satisfactory explanation for its occurrence.

2.2.2 Manner of articulation

As noted above, Nilotic languages typically have stops and nasals at corresponding places of articulation, with a general pattern of five place contrasts (labial, dental, alveolar, palatal, velar) in Western Nilotic languages, and four place contrasts (labial, alveolar, palatal, velar) in Southern and Eastern Nilotic languages. In a small number of languages, a corresponding series of prenasalised stops is also attested, for example in Western Nilotic Dholuo (Tucker, 1994) and Alur (Ringe, 1948), and including for labial-velar articulations in Western Nilotic Belanda Boor (Von Heyking, 2013) and Eastern Nilotic Kakwa (Onziga & Gilley, 2012). However, across Nilotic languages, the most variation in manners of articulation is in the extent to which fricatives also occur at the primary places of articulation. As the following discussion will show, the status of fricatives in relation to stops at similar places of articulation is also not always entirely clear, particularly in the coronal space.

In Western Nilotic languages, fricatives are uncommon. In the Dinka-Nuer group, the only fricatives reported are the marginal glottal fricative noted above for Nuer, and a voiced velar segment in Dinka varieties which is either a fricative (Andersen, 1987) or an approximant (Andersen, 1993; Remijsen & Manyang, 2009). Contrastive fricatives are similarly absent for many languages of the Northern Luo group, though fricatives may occur as variants of selected stops, for example in Shilluk, Päri, and Mayak (Gilley, 1992, p. 36, Remijsen et al., 2011, p. 113, Andersen, 1988a, p. 111, Andersen, 1999a, p. 83). Kurmuk is unusual in that it has fricatives /ʃ/ and /z/, which likely derive from palatal stops originally part of the consonant inventory (Andersen, 2007), while Belanda Boor has alveolar /s/ and labial-velar /f/, presumed to be reflexes of /c/ and /p/ segments which are no longer part of the system (Von Heyking, 2013). Some languages in the Southern Luo group of Western Nilotic have fricatives, some with a low functional load; /f/, /s/, and /h/ occur in Dholuo (Tucker, 1994), /s/ occurs in Kumam (Hieda, 2011), and Alur has /f/, /s/, /z/, and /h/ (Ringe, 1948; Heusing, 2006; Dimmendaal, 1995). For Lango, fricatives only occur as intervocalic allophones of voiceless obstruents, but the palatal obstruents are described as affricates rather than stops (Noonan, 1992).

Fricatives are more common in the other two branches of Nilotic. In all Southern Nilotic languages, /s/ is reliably found; it is the only fricative used in Endo (Zwarts, 2004), while in Pökoot, a velar fricative is also described (Crazzolara, 1978; Rottland, 1982; Baroja et al., 1989), and Kipsigis has a possible /h/ (and the palatal obstruent is described as an affricate) (Toweett, 1979). In Nandi, other fricatives only occur as lenited variants of intervocalic voiceless stops (Creider & Creider, 1989). Datooga stands out in that it has fricatives /f/, /s/, /ʃ/, and possibly /h/ (Rottland, 1983), while Omotik is unusual in that it has a lateral fricative /ɬ/ in addition to /s/ (Rottland, 1982). Eastern Nilotic consonant inventories also reliably include /s/; among the Bari languages, /s/ is the only fricative phoneme in Bari itself, and may be produced as [ʃ] or [ts] (Spagnolo, 1933), and also be an allophone of /t/ and /k/ in a number of varieties (Vossen, 1982). Mundari and Kuku similarly have at least /s/; for Kuku, [h] may also occur as a variant of /k/ (Stirtz, 2014a; Cohen, 2000). In both Kuku and Bari, the voiced palatal stop may be produced as an affricate (Cohen, 2000; Vossen, 1982). In Kakwa, in addition to /s/, /z/ occurs as a free variant of the voiced palatal stop, and is apparently preferred in some dialect areas (Onziga & Gilley, 2012). In Pojulu, Kuku, and Nyangwara, /p/ is produced as [f] intervocalically (Vossen, 1982).

Among the non-Bari Eastern Nilotic languages, a similar range of fricative inventories and possible stop-fricative relationships can be observed. For Toposa and Turkana, only /s/ is phonemic; in Turkana it may be produced [z], [θ], or [ð], and fricative or affricate productions are also noted as variants of /p, t, c, k/ (M. C. Schröder, 2004; Dimmendaal, 1983b; Heine, 1980). For Karimojong, /s/ and /z/ (also produced [ð]) are proposed as contrastive, in addition to an infrequently-used velar fricative, and palatoalveolar affricates /ts/ and /dz/ are noted instead of palatal stops (Novelli, 1985). Ateso has at least

/s/ (Vossen, 1982), though Barasa (2017) also lists /ʃ/, and according to Schrock (2014), /f/, /h/, and /v/ are used in loanwords. The fricative series in Maa varieties minimally includes /s/, but a complicated and seemingly changing relationship between segments such as [c], [ʃ] and [h] is also recognised (D. L. Payne, 2012); in some varieties [c] and [ʃ] are in complementary distribution (or are free variants), while in others they appear to contrast, and in some regions [h] may be more common than [ʃ], and potentially in contrast with [ʃ] for some speakers (Tucker & Mpaayei, 1955; Heine, 1980; Vossen, 1982; Levergood, 1987; D. L. Payne, 2012). Arusa Maa has a labial fricative (which can be either voiced or voiceless) in addition to /s/ and /ʃ/, and records for Ongamo suggest the fricative series may have been /β/, /s/, /ʃ/, and /h/ (Heine & Vossen, 1975; Vossen, 1982). Languages of the Lotuxo group tend towards larger fricative inventories; though Vossen (1982) notes only /s/ as phonemic, and analyses [f, ð, x] as intervocalic variants of /p, t, k/, Muratori (1938) views at least /f/, /s/, and /x/ as distinctive, and Coates (1985) notes /f/, /s/, /θ/, and /h/ as phonemic. It is worth noting that the contrast Coates proposes between /θ/ and /t/ corresponds to the contrast between singleton /t/ and geminate /tː/ proposed in Muratori's earlier work, discussed further in 2.2.4. For Dongotono, Lokoya, and Lopit, dental fricatives have not been suggested, but as for Otuho, Vossen (1982) describes /s/ as phonemic and fricative productions such as [f, ɸ] and [x, ɣ, h] as intervocalic variants of /p/ and /k/ (though with some speculation that a labial fricative may be contrasive), while later work points towards /f/, /s/ and /x/ (or /h/) as contrasting with stops at similar place of articulation (Turner, 2001; Stirtz, 2014b).

In addition to the obstruents and nasals discussed, all Nilotic languages minimally have a single rhotic, lateral, and a palatal and labial-velar glide. This is the typical remaining sonorant inventory for both Southern and Western Nilotic languages. For the rhotic, the manner of articulation is not specified in all descriptions, but where it is, it is mostly described as a trill, though for Western Nilotic Lango (Noonan, 1992) and Southern Nilotic Nandi (Creider & Creider, 1989) it is described as a tap. In both families, the single alveolar lateral approximant is only supplemented by the aforementioned lateral fricative in Omotik, and some possible length contrasts, discussed further in 2.2.4. As for the lateral, palatal and labial-velar glides may exhibit a length contrast in some

Western Nilotic cases, and an additional labio-palatal glide has been suggested for Dinka (Andersen, 1993). Within the Eastern Nilotic family, liquids and approximants used in Bari varieties show the same general pattern of a single lateral, a rhotic (described as a trill, where specified), and glides at two places of articulation (Spagnolo, 1933; Vossen, 1982; Stirtz, 2014a; Cohen, 2000; Onziga & Gilley, 2012). However, in some of these languages, a consonant described as an implosive palatal glide is also suggested, e.g. for Bari, Mundari, and Kuku (specified as a glottal palatal glide). The proposed implosive/glottal glide appears to fill the gap left by the lack of a palatal stop in the implosive stop series, discussed further in 2.2.3, though closely-related Kakwa does have an implosive palatal stop (Onziga & Gilley, 2012). Given that implosion is generally held to be a characteristic of obstruents, the nature of the proposed implosive glide clearly warrants further investigation, as also noted by Dimmendaal (1988, p. 14); it may be that it is indeed a glide, with some audible laryngeal difference compared to the other palatal glide. Among the non-Bari languages, those in the Teso-Turkana group also have the typical single lateral, rhotic (trill), and a palatal and labial-velar glide (Dimmendaal, 1983b; Heine, 1980; M. C. Schröder, 2004; Novelli, 1985; Vossen, 1982; Barasa, 2017; Schrock, 2014).

For the Lotuxo-Maa languages of the Eastern Nilotic family, some key differences are observed. For all the Maa languages, two rhotics, a tap /ɾ/ and a trill /r/, are consistently found, as well as four rather than two glides (Heine, 1980; Vossen, 1982; Tucker & Mpaayei, 1955; Levergood, 1987; Heine & Vossen, 1975), a typologically uncommon occurrence. The glides /w/ and /j/ are suggested to contrast with /wː/ and /jː/,[4] and the latter are variously described as long, 'strong' or fortis consonants, a matter discussed in more detail in relation to glides and other consonants in 2.2.4. A single lateral is typical among Maa languages, though a long lateral (and a long nasal) may occur in a very small number of words (Hollis, 1905, p. 43). The Lotuxo languages have similar approximant inventories. Vossen (1982) notes only one rhotic for Otuho, Dongotono, Lokoya and Lopit, but descriptions by Muratori (1938) and Coates (1985) indicate that Otuho has

[4]These glides are written as /wu/ and /yi/ in some of the literature on Maa languages, e.g. Tucker and Mpaayei (1955).

at least a tap and a trill.[5] For Lopit, Turner (2001) describes both a tap and a trill, and Stirtz (2014b) similarly observes two rhotics, though analyses the longer of the two as a sequence of identical adjacent consonants rather than as a contrastive segment. Vossen (1982) also only notes a single lateral across the languages, but both Muratori (1938) and Coates (1985) note a 'strong' /lː/ contrasting with a 'weak' or short /l/ in Otuho, and the possibility of long and short lateral approximants is also noted for Lopit (Turner, 2001; Stirtz, 2014b). However, all authors note four, rather than two, contrastive glides, as for Maa, with /wː/ and /jː/ described as long or 'strong' in Otuho and primarily as long in Lopit.

2.2.3 Laryngeal and airstream features

All Western Nilotic languages use voicing to distinguish two stop series, and accordingly a contrast between voiced and voiceless stops is found at all five primary places of articulation for languages of the Dinka-Nuer group and most languages of the Northern Luo group (Andersen, 1993; Remijsen & Manyang, 2009; Yigezu, 1994; Faust & Grossman, in press; Reid, 2010; Gilley, 1992; Remijsen et al., 2011; Andersen, 1988a; Reh, 1996; Andersen, 2004), and at the four to five primary places of articulation for languages of the Southern Luo group (Tucker, 1994; Hieda, 2016, 2011; Noonan, 1992). The voicing distinction extends to the labial-velar stops attested for some languages (Von Heyking, 2013; Dimmendaal, 1995; Heusing, 2006), and is a distinction among obstruents more generally for languages in which selected voiceless stops have changed to voiceless fricatives (Andersen, 2007; Von Heyking, 2013), which rarely contrast with voiced fricatives in Nilotic languages. In some cases the voiced alveolar stop has an implosive variant, as in Mayak (Andersen, 1999a), or is always produced as an implosive, as in Kurmuk (Andersen, 2007), and Alur is described as having implosive stops contrasting with both voiced /b/ and /d/ and voiceless /p/ and /t/ (Dimmendaal, 1995; Heusing, 2006). In contrast, Southern Nilotic languages typically do not exhibit a voicing contrast; for Nandi, Endo, Kipsigis and Omotik, only a single, voiceless stop series is described (Creider &

[5] Coates in fact proposes two taps contrasting with the rhotic, one produced with the tongue tip, and one with the tongue blade, but see 2.2.4 for further discussion of the latter.

Creider, 1989; Zwarts, 2004; Toweett, 1979; Rottland, 1982). Pökoot may have a voicing distinction for some individual stops (Rottland, 1982), but Datooga is reportedly the only Southern Nilotic language with a systematic voicing distinction, albeit with a limited functional load (Rottland, 1983). Interestingly, Rottland (1983) speculates that the contrast could potentially be analysed as one of length instead, as discussed further in 2.2.4.

In the Eastern Nilotic family, all languages have both a voiced and voiceless stop series. Those in the Bari group have an additional implosive series. Though implosives are not widespread across Nilotic languages, they are common for languages of the Sudanic belt region, as for labial-velar stops (Clements & Rialland, 2008). In Bari, Kuku and Kakwa, implosives at the bilabial, alveolar, and palatal places of articulation are proposed, though as noted in 2.2.2 the palatal implosive is described somewhat unusually as a glide (Spagnolo, 1933; Vossen, 1982; Cohen, 2000; Onziga & Gilley, 2012). For Mundari, Stirtz (2014a) notes an alveolar implosive stop as well as an implosive palatal approximant but no bilabial implosive. Among the pulmonic stops, the voicing distinction is found at all places of articulation in the Bari languages, including for labial-velar consonants in Kuku and Kakwa and retroflex consonants in Kakwa (Cohen, 2000; Onziga & Gilley, 2012), except in cases where the voiced palatal stop does not have a voiceless counterpart. Among the non-Bari Eastern Nilotic languages, there is typically also a voicing contrast at the four primary places of articulation. Implosion is not used to contrast two sets of voiced stops, though it is sometimes described as an inherent or variable characteristic of the voiced stop series. This has been observed across Teso-Turkana languages (M. C. Schröder, 2004; Novelli, 1985; Dimmendaal, 1983b; Heine, 1980; Schrock, 2014; Barasa, 2017; Vossen, 1982; Tucker & Bryan, 1966), as well as for Maa varieties (Heine, 1980; Vossen, 1982; Tucker & Mpaayei, 1955; D. L. Payne, 2012), though for Arusa Maa and Ongamo the voiceless obstruent series comprises fricatives in place of some stops (Levergood, 1987; Heine & Vossen, 1975; Vossen, 1982). A contrast between voiced and voiceless stops has similarly been noted for languages of the Lotuxo group, including Lopit, but implosion is less consistently noted as a feature of the voiced series (Muratori, 1938; Tucker & Bryan, 1966; Vossen, 1982; Coates, 1985; Turner, 2001; Stirtz, 2014b). As yet, no instrumental data are available for obstruent contrasts in these languages.

2.2.4 Length and strength

For a number of Nilotic languages, additional consonantal distinctions are noted which are described as drawing on length or 'strength', a term used in various ways and sometimes relating to impressions of length but also fortition, sonority, and articulatory configuration (see 5.2.7 and 5.2.8 for further discussion). For the most part, these have not been discussed in detail, so their status in individual language phonologies is not always clear, and the varying terminology used by researchers working across and within languages suggests that the contrasts may have a range of percepts. In this overview, the terms 'strong' and 'weak' are used as they appear in the Nilotic literature, without claim to any particular set of correlates across the languages, but additional details are provided where available.

In the Western Nilotic language family, consonant gemination occurs as a result of morphophonological processes in a number of languages. For Thok Reel, a sequence of identical stops at a morpheme boundary optionally results in a geminate stop, though usually a singleton is produced Reid (2010, p. 50), and some Nuer examples suggest a similar possibility (Faust & Grossman, in press), but processes of this sort do not appear to have been described for other Dinka-Nuer languages. Among the Southern Luo languages, gemination resulting from morphophonological processes has been noted for Kumam and Acholi (Hieda, 2011, 2016), and in Lango geminates occur with grammatical significance (Noonan, 1992), but none appear to have been noted for Alur or Dholuo. Morphophonological gemination is quite common for various stops, nasals, liquids and glides in Northern Luo languages such as Anuak, Päri, and Jumjum (Reh, 1996; Andersen, 1988a, 2004). Long sonorants, including glides, are also contrastive in Päri, and various long consonants are contrastive in Jumjum nouns. For Shilluk, another Northern Luo language, Gilley (1992) describes similar processes at morpheme boundaries resulting in consonants which she instead describes as fortis, using the term to capture a range of perceived differences including length.[6] In a quantitative investigation of these obser-

[6]Gilley (1992, pp. 26–27) notes that the production of fortis consonants varies; fortis sonorants are described as geminate articulations when produced in slow, deliberate speech, but in speech produced at normal speed, "the difference is certainly not one of length". For fortis stops, the segments are long when produced in slow speech, but in rapid speech, they are instead reportedly produced with aspiration.

vations, Remijsen et al. (2011) analyse closure duration of single and adjacent identical segments at morpheme boundaries, and find that differences in duration are not significant. The researchers suggest that although the fortition/gemination process may be present for some individuals, it is not consistently realised, and likely interacts in significant ways with lenition processes.

For Southern Nilotic languages, no such regular processes have been noted, but some observations of inherent differences in consonant duration are of interest. As noted in 2.2.3, Rottland (1983) speculates that the Datooga voiceless/voiced distinction could alternatively be analysed as one of length. This suggestion is based on his impression that voiceless /t/ is almost always geminated, though possible gemination is less clear for /p/, /c/, and /k/. Rottland (1983) also suggests that the voiceless stop series in Datooga may have been innovated based on the sequences of identical voiced stops from which many underlying voiceless stops apparently originate. For Kipsigis and Nandi, both /t/ and /k/ are described as typically having a geminate articulation (Toweett, 1979; Rottland, 1982). For Eastern Nilotic languages, the possibilities for long or 'strong' consonants appear to vary. Some observations for languages in the Bari group indicate that, as for a number of Western Nilotic languages, gemination may occur as a morphophonological process across morpheme boundaries. This is noted for Bari (Vossen, 1982, p. 173) and for Mundari (Stirtz, 2014a), but gemination does not appear to have a contrastive function in these languages. For Kuku, both long and short consonants occur, but while the long consonants are sometimes the result of a specific suffixation process on verbs, their occurrence is not entirely predictable (Cohen, 2000, pp. 12–13). In linguistic descriptions of languages in the Teso-Turkana group, no gemination processes are noted. However, Vossen (1982) records some instances of geminate [jː] in data for Ateso, and Dimmendaal (1983b, p. 14) finds that in Turkana, a long [wː] is possible in some words (corresponding to sequences of velar or bilabial obstruents plus glide in cognates in Ateso), though neither proposes these long glides as contrastive.

The possibility of distinctions between glides at the same place of articulation becomes more intriguing once patterns in the Maa languages are considered. As noted in 2.2.2, the Maa languages all contrast a tap and a trill, but furthermore, all are also described as having four glides – two palatal, /j/ and /jː/, and two labial-velar, /w/ and /wː/ (Tucker & Mpaayei, 1955; Heine & Vossen, 1975; Heine, 1980; Vossen, 1982; Levergood, 1987; D. L. Payne, 2012). Contrasts of this sort are typologically uncommon, though they are found in a range of language families around the world (Maddieson, 2008). As noted at the beginning of this chapter, there is some variation in how these are represented in the literature, but they are shown here following IPA conventions. For Maa languages, /w/ and /j/ are variously described as 'weak', lenis, and/or short, compared to 'strong', fortis and/or long /wː/ and /jː/ (Tucker & Mpaayei, 1955; Tucker & Bryan, 1966; Heine & Vossen, 1975; D. L. Payne, 2012), and impressions of a closer quality are also noted for the latter (Tucker & Bryan, 1966; Levergood, 1987). These observations suggest that while some researchers have perceived duration differences between the glides in each set, there may be other characteristics distinguishing pairs of glides. Apart from among rhotics and glides, no other contrastive length/strength differences are proposed among the Maa languages, nor have any morphophonological processes of gemination been noted. Hollis (1905, p. 43) notes the presence of /lː/ and /nː/ in a number of demonstratives, and while Tucker and Mpaayei (1955, p. xv11) acknowledge this, they note that it has no semantic significance in Maa. In terms of rhotics and glides, inventories for Lotuxo languages look similar to those for Maa languages. Descriptions for Otuho, Lokoya, Dongotono and Lopit overall indicate both a tap and a trill for at least Otuho and Lopit, and four contrastive glides in all the languages (Muratori, 1938; Vossen, 1982; Coates, 1985; Turner, 2001; Stirtz, 2014b). Glides /wː/ and /jː/ are described by most researchers as long, compared to short /w/ and /j/, though for Otuho the contrast is described as 'strong' compared to 'weak' instead (Coates, 1985) or as well (Muratori, 1938). For Lopit, Turner (2001) describes /wː/ and /jː/ as being both longer and slightly more fricated than /w/ and /j/. As for the Maa languages, then, the nature of glide contrasts among the Lotuxo languages is not entirely clear; it seems that at least duration differences may be involved, but that other cues may potentially also be available. This is particularly interesting given suggestions that glide length contrasts may be less robust in perception (Kawahara, 2007) and possibly production (Aoyama & Reid, 2006) compared to length contrasts for other consonant types.

Unlike the Maa languages, however, Lotuxo languages seemingly have additional contrasts drawing on length or 'strength'. These include a distinction between 'strong' /lː/ compared to 'weak' or short /l/ for Otuho laterals (Muratori, 1938; Coates, 1985), and between long /lː/ and short /l/ in Lopit (Turner, 2001; Stirtz, 2014b), though as for the rhotic, Stirtz (2014b) does not analyse this as contrastive. Otuho is also described as having a 'strong' /nː/ contrasting with a 'weak' or short /n/ (Muratori, 1938; Coates, 1985), and a long /nː/ is recorded in at least some Lopit examples (Turner, 2001; Stirtz, 2014b). However, in terms of length/strength contrasts, the main thing that sets languages of the Lotuxo group apart from others in the Eastern Nilotic family is the proposed length/strength contrasts among alveolar stops. Vossen (1982) notes both an alveolar geminate /tː/ and dental singleton /t̪/ for Otuho, Dongotono, Lokoya, and Lopit, though also notes that in Otuho, the singleton is realised as voiced dental fricative [ð] intervocalically. Coates (1985) describes the Otuho contrast as instead between alveolar /t/ and /θ/, while Muratori's impressions refer to /tː/ as a strong, dental segment similar to Italian /tː/, compared to the alveopalatal /t/ produced with a 'weak' sound (Muratori, 1938). Muratori also notes a corresponding contrast among the voiced alveolars, with /dː/ as a strong, dental sound, and /d/ as a weak, slightly palatal sound, which appears to correspond to Coates' proposed contrast between 'strong' /d/ and a 'weak', short segment described as an alveolar flap articulated with the tongue blade rather than tip. For Lopit, the contrast between /tː/ and /t/ observed by Vossen (1982) is supported by findings presented by both Turner (2001) and Stirtz (2014b), who both also find evidence for an equivalent contrast between voiced /dː/ and /d/ (though Stirtz, as for the rest, does not analyse it as phonemic). Turner (2001) also suggests /sː/ contrasting with /s/, but notes it is the phoneme he is most doubtful about, and Vossen (1982) notes that some examples of medial [pː], of uncertain status, have been noted for Lokoya and Lopit.

2.3 Nilotic Vowels

2.3.1 'Advanced Tongue Root'

A key characteristic of Nilotic vowel systems is the widespread use of 'Advanced Tongue Root' (ATR) as a phonological feature distinguishing pairs of similar vowels, and frequently also the basis of a vowel harmony system. Because ATR interacts in crucial ways with other means of contrasting vowels within the inventory of each language, some general description of ATR is necessary before turning to the language-specific details of Nilotic vowel systems. Aspects of ATR phonology, typology, and auditory, acoustic and articulatory correlates are discussed in more detail in 4.2 with reference to crosslinguistic findings. ATR is a feature which is proposed for various languages around the world, but in particular for a great many languages of both the Nilo-Saharan and the Niger-Congo phyla. Very generally, it is held to distinguish pairs of vowels sharing the same (or similar) height, frontness-backness, and rounding specifications (Casali, 2008, p. 499). For languages with such a contrast, vowels are typically divided into two sets: those with [+ATR], and those with [-ATR] (or RTR, 'Retracted Tongue Root'). In a symmetrical system of 10 vowels, of the sort thought by some to have existed in proto-Nilo-Saharan (e.g. Blench, 1995, p. 89, though see also Ehret, 2001, p. 43), the 5 [+ATR] vowels are often represented as /i, e, ə, o, u/, and the 5 [-ATR] vowels are typically represented as /ɪ, ɛ, a, ɔ, ʊ/. Variants are occasionally seen for the close vowels, and the [+ATR] counterpart to the open vowel is also sometimes represented as /ʌ/ or /ä/, and many languages make use of only a subset of these possible contrasts. The label 'Advanced Tongue Root' emerged following early radiographic work which revealed a more anterior tongue root position for vowels of the set often described as having closer vowel qualities (Ladefoged, 1964; Stewart, 1967). Later instrumental work shows that this is one of several articulatory correlates of an overall less constricted vocal setting for these vowels (see 4.2.3), acoustically co-occurring with a lower first formant frequency (F1) and a range of secondary correlates (see 4.2.4).

These two sets of vowels form pairs which are important in the harmony processes often attested alongside (and sometimes diagnostic for) ATR contrasts in African languages. Vowel harmony requires that vowels in a given domain, such as the phonological word, share a given feature or bundle of features (Rose & Walker, 2011). For languages with harmony systems drawing on the ATR feature, there is a preference for all vowels in a word to agree in terms of their [+ATR] or [-ATR] specification, and phonological processes operate to maintain this to the extent possible within different language-specific parameters (Casali, 2003, 2008). In root morphemes, vowels specified for either [+ATR] or [-ATR] are often not found to co-occur with vowels of the opposite ATR specification, and the addition of affixes with an opposing ATR specification may trigger a change in ATR quality for other vowels in the word. Vowels are then realised as their harmonic counterparts, which are the vowels of similar height, backness and rounding but from the opposite ATR set. These systems have also been referred to as "cross-height" harmony systems (see e.g. Clements, 2015).

Among languages of Africa, including within the Nilotic family, [+ATR] is often the dominant feature, and it is the [-ATR] vowels which are compelled to change to [+ATR] in relevant contexts (Clements, 2000; Clements & Rialland, 2008; Casali, 2003, 2008). However, some correlations have been observed between dominance patterns and the specific contrasts in a vowel inventory; for example, in a survey of 110 Niger-Congo and Nilo-Saharan languages, 69 languages with vowel inventories including an [ATR] contrast among the close vowels show [+ATR] dominance; only 9 show instances of [-ATR] dominance, and in many cases this is in addition to possibilities for [+ATR] dominance. However, among languages with an [ATR] contrast only among the mid (and not close) vowels, [-ATR] dominance is more common, as observed for 37 languages in the sample (Casali, 2003, 2008). Languages may differ in the directionality of the spread of harmony, including the extent to which harmony may operate both right-to-left as well as left-to-right, and also in whether roots and affixes are equally able to trigger harmony processes. Such processes may not apply to all vowels in an inventory, particularly if there is an asymmetry in the set of [+ATR] compared to [-ATR] vowels. A common example among Nilotic languages, and African languages more generally, is cases in which the open vowel /a/ (which is typically [-ATR]) lacks a [+ATR] counterpart, and may combine with vowels of both sets and, frequently, interrupt the spread of ATR harmony (Casali, 2008, pp. 527–532). While ATR harmony is widespread among Nilotic languages, for some languages, particularly those of the Western Nilotic family which tend towards stem-internal inflection, it does not occur, though it may well have historically (e.g. Andersen, 1987; Andersen, 1999c; Remijsen et al., 2011).

2.3.2 Height, backness and rounding

Nilotic languages tend to have 7–10 basic vowel quality contrasts, with distinctions along a number of different parameters including ATR, height, backness and rounding. Though proto-Nilotic is thought to have likely exhibited a canonical 10-vowel sytem of 5 [+ATR] and 5 [-ATR] vowels (Dimmendaal, 1988)[7], there is great diversity in Nilotic vowel systems today. Features such as ATR may be differently implemented across languages, and the role of voice quality differences, and the extent to which length is used for vowel contrasts, also varies (discussed further in 2.3.3, 2.3.4). Furthermore, in some languages there are interactions between these features. In terms of the basic quality contrasts, however, the main difference across Nilotic languages is whether there is a contrast between one or two 'open' vowels, and whether there is a reliable contrast between pairs of front and back mid-vowels, or, in some languages, pairs of front and back close vowels. As noted by Dimmendaal (1988), these matters, particularly in relation to the status of the tenth vowel, have implications for understanding crosslinguistic relationships and the language-specific workings of vowel harmony, and are particularly in need of further investigation informed by comprehensive linguistic data.

Among Western Nilotic languages, an inventory of 9–10 vowel qualities is common. Languages of the Southern Luo group are typically described as having a series of [+ATR] compared to [-ATR] vowels; for Kumam, Acholi and Lango, this includes a tenth vowel, transcribed as /ɑ/ or /ə/ and labelled [+ATR] (Denning, 1989; Noonan, 1992; Hieda, 2011, 2016). Alur and Dholuo appear to lack the contrastive tenth vowel (Ringe, 1948; Jacobson, 1978). Acoustic data for Acholi, Lango and Dholuo show that the [+ATR] vowels typically have a lower F1 than corresponding [-ATR] vowels (Denning, 1989, p. 45);

[7]Though with some uncertainly surrounding the historical status of a [+ATR] 'open' vowel.

Noonan, 1992, pp. 25–27; Jacobson, 1978; Swenson, 2015). Similar observations obtain for the Northern Luo languages. Anuak, Päri, Belanda Boor and Shilluk are all described as having 10 distinct vowel qualities, though some of the contrasts may be marginal (Reh, 1996; Andersen, 1989; Von Heyking, 2013; Remijsen et al., 2011). Acoustic investigations by Remijsen et al. (2011) show that lower F1 values are a significant correlate of the [+ATR] compared to [-ATR] vowels in Shilluk. Differences in the energy distribution, as evidenced by spectral emphasis, are a more variable, secondary correlate. In the Burun group of Northern Luo languages, only Kurmuk has a 10-vowel system (Andersen, 2007); Mayak and Jumjum have 8 contrastive vowel qualities, and Mabaan has 7 (Andersen, 1999b, 2004, 1999c). For Western Nilotic languages of the Dinka-Nuer family, a vowel inventory comprising 7 distinct vowel qualities with no ATR contrast is typical, and has been noted for different varieties of Dinka (Andersen, 1987; Remijsen & Manyang, 2009), and also observed for Thok Reel, with supporting formant frequency data (Reid, 2010). They are generally represented as /i, e, ɛ, a, ɔ, o, ʊ/, showing two series of mid vowels but only one series of close vowels, and one open vowel. These quality contrasts are, however, found in two distinctive voice qualities, with additional length differences, discussed further in 2.3.3 and 2.3.4. Proposals for Nuer range from 7–10 vowel qualities, also with possible voice quality and length differences (Yigezu, 1994; Frank, 1999; Storch, 2005; Faust & Grossman, in press; Monich, 2017). For a number of Western Nilotic languages, particularly in the Dinka-Nuer group, various diphthongs are also proposed (e.g. Andersen, 1987; Faust & Grossman, in press); in some research these are instead analysed as sequences of glides and vowels (e.g. Remijsen & Manyang, 2009; Reid, 2010).

A 10-vowel system of 5 [+ATR] and 5 [-ATR] vowels is most typical of Southern Nilotic languages. Inventories of this sort are described for Endo, Nandi, Tugen and Kipsigis (Zwarts, 2004; Creider & Creider, 1989; Local & Lodge, 1996; Toweett, 1979), and the two sets are utilised in harmony processes in all languages. For Kipsigis, some closing diphthongs are also noted. For Pökoot, some descriptions note 10 vowel qualities, in a 'close' and 'open' series (Crazzolara, 1978), though in other work it is not clear if a close/open distinction applies across the inventory (Baroja et al., 1989), and the inventory is alternatively proposed to include only 5 vowel qualities (Rottland, 1982). Datooga is described as having 7 contrastive vowel qualities, and lacks an ATR contrast among the close vowels, as well as for the open vowel (Rottland, 1983). 8 vowel qualities are observed for Omotik, with the ATR contrast absent only among the close vowels (Rottland, 1982). For Tugen, Local and Lodge (2004) present acoustic data collected with one speaker, and show that the [+ATR] vowels have lower F1 values compared to [-ATR] vowels. Local and Lodge (2004) also investigate a range of other acoustic differences correlating with the presence of either [+ATR] or [-ATR] vowels, but look beyond the vowel segments themselves, with intriguing results. Their observations include place of articulation differences for coronals, differences in the presence of a burst release for coda consonants, and differences in both consonant and vowel duration. Based on these findings, Local and Lodge (2004) problematise the focus on vowels in ATR harmony systems, noting that the additional effects on consonant realisations and aspects of prosody cannot easily be captured under one label, and that ATR distinctions are best considered to apply across syllables, rather than just vowels. This raises important questions about the extent to which overall articulatory setting should be taken into account in investigations of languages with these types of vowel systems, but has not seemingly been taken up in the study of Nilo-Saharan languages.

Some of the Eastern Nilotic languages in the Bari family have a full 10-vowel inventory with an ATR contrast and vowel harmony, such as Kuku (Cohen, 2000) and Bari itself (Spagnolo, 1933; B. L. Hall & Yokwe, 1981). Stirtz (2014a) proposes only 8 distinctive vowels for Mundari, and the inventory for Kakwa is further reduced, with only 7 contrastive vowel qualities (Onziga & Gilley, 2012). Elsewhere in Eastern Nilotic, contrasts between 9 vowel qualities are found almost without exception. 9-vowel systems are attested for Turkana, Toposa, and Ateso (Dimmendaal, 1983b; Noske, 1996; M. Schröder & Schröder, 1987; M. C. Schröder, 2004; Schrock, 2014; Barasa, 2017), though for Karimojong, 13 distinct vowel qualities (some marginal) are described (Novelli, 1985; Lesley-Neuman, 2007). The vowel systems of Teso-Turkana languages are also cross-cut by laryngeal differences, discussed in 2.3.3. Ateso is so far the only Eastern Nilotic language for which articulatory investigations of ATR production have taken place; based on radiographic data, Lindau et al. (1972) find some differences in tongue root position for [+ATR] compared to [-ATR] vowels, but differences in tongue body height appear to be the major gestural correlate. Accompanying acoustic results indicate a lower F1 for [+ATR] vowels.

The same finding of lower F1, together with some secondary cues, has been observed for Maa [+ATR] vowels (Guion et al., 2004) which, as is typical of Maa varieties, constitute part of a 9-vowel inventory with associated harmony (Tucker & Mpaayei, 1955; Quinn-Wreidt, 2013). In some cases, 10 vowels have been listed (e.g. Heine, 1980; Vossen, 1982, but with remarks that the [+ATR] and [-ATR] /a/ are identical (and therefore seemingly proposed for morphophonological convenience). This is similar to many descriptions of languages in the Lotuxo family; for Otuho, Dongotono, Lokoya and Lopit, Vossen (1982, pp. 188–193) proposes two sets of five vowels, distinguished by ATR, but also notes that [+/-ATR] open vowels are both represented as /a/ because "they cannot be distinguished phonetically". In earlier work on Otuho, Muratori (1938, p. 3) held that the two could sometimes be distinguished, and in Coates' (1985) later phonology sketch for Otuho she did apparently find a contrast among the open vowels according to [ATR] specification, with the caveat that this "is not considered important by native speakers" (Coates, 1985, p. 96). For Lopit, Turner (2001) proposes, as Vossen (1982) did, 10 vowels distinguished by [ATR] specification; however, he notes that Lopit speakers perceive no difference between [+ATR] and [-ATR] /a/, and that he hears them as phonetically very similar. In more recent work, Stirtz (2014b) instead suggests an inventory of only five vowels, with no ATR distinction. Apart from the latter case, these studies of Lotuxo languages all note that the [ATR] contrast appears to be used for vowel harmony processes, but these are not discussed in detail. For many Eastern Nilotic languages, various diphthongs appear to also be used, though in some instances their status in relation to vowel sequences, and sequences of glides and vowels, is not yet clear.

2.3.3 Phonation

For Nilotic languages in which an ATR contrast is proposed, some researchers note auditory impressions of differences in the voice quality or timbre of [+/-ATR] vowels, in addition to differences in vowel height. Descriptors vary; for Western Nilotic Kumam, Hieda (2011) describes the [+ATR] vowels as having a "darkish tone color" while the [-

ATR] vowels are perceived as "clear", and for Lango, Noonan (1992) suggests that the [-ATR] vowels may be slightly creaky, while noting that any difference in voice quality is likely very subtle. For Anuak, the [+ATR] vowels are suggested to have a breathy voice (Reh, 1996). For Shilluk, Gilley (1992) describes the [+ATR] set (preferring the label [+Expanded Pharynx]) as having a muffled or breathy quality, and the [-ATR] set as having a brassy quality, drawing on terminological recommendations advanced by Jacobson (1980) based on observations for Dinka. As noted in 2.3.2, acoustic results point towards F1 as the major correlate of ATR category in Shilluk, with differences in the energy distribution as a secondary correlate only. Similarly, for Acholi, for which there is speculation of voice quality differences between [+ATR] and [-ATR] vowels, vowels of each set are reliably distinguished by F1, and measures such as spectral tilt show no consistent correlation across vowels (Denning, 1989, p. 45), suggesting no major difference in vocal effort (see 4.2.4). For Southern Nilotic Nandi, the [+ATR] vowels have been impressionistically described as 'hollow', with a 'full quality', while the [-ATR] vowels have been described as 'tense' or 'tight' (Creider & Creider, 1989). Interestingly, for Tugen, it is the [-ATR] rather than the [+ATR] set which is perceived as having a more breathy voice quality, and measurements of the vocal fold open quotient, made using electroglottography, provide support for these impressions (Local & Lodge, 2004). In contrast, for Eastern Nilotic Maa, electroglottographic findings suggest a breathier quality for vowels of the [+ATR] set (Guion et al., 2004), which is more expected given the impressionistic observations noted above for [+ATR] vowels in other languages. For Turkana, [+ATR] vowels are perceived to "sound somewhat breathy", except for [+ATR] mid vowels in the environment of specific [-ATR] vowels, and the [-ATR] vowels are described as having a "hard" voice, or sounding "tense" or "harsh" (Dimmendaal, 1983b, p. 27). Noske (1996) does not perceive breathiness for Turkana [+ATR] vowels, but notes that the [-ATR] vowels sound "choked". As noted in 2.3.1 and discussed further in 4.2.3, articulatory evidence points towards an overall less constricted vocal setting for vowels in the [+ATR] set, particularly with regard to postures of the lower vocal tract (Esling, 2005; Edmondson & Esling, 2006; Edmondson, Padayodi, Hassan & Esling, 2007; Padayodi, 2008; Edmondson, 2009). Apart from the reportedly breathy quality of [-ATR] vowels in

Tugen, the phonetic descriptors noted here accord well with a model in which laryngeal constriction is a key component in the production of [-ATR] vowels.

While the literature discussed above suggests voice quality differences or similar percepts as as additional correlates to ATR contrasts, for some Nilotic languages, voice quality distinctions are phonemic in their own right. This has long been noted for a number of Western Nilotic languages in the Dinka-Nuer group. While there is clearly a historical relationship between ATR contrasts and contrastive voice quality in Nilotic languages, either with ATR contrasts emerging from original voice quality contrasts (Denning, 1989; Ohala, 1994), or alternatively being the precursor to voice quality contrasts (Andersen, 1999c), this is now a significant source of difference in Nilotic vowel systems. Thok Reel is described as having a contrast between modal and breathy voiced vowels (Reid, 2010), and Nuer appears to also make use of such a contrast (Frank, 1999; Yigezu, 1994; Faust & Grossman, in press; Monich, 2017). A number of varieties of Dinka are also described as having two contrastive voice qualities, which may for the most part freely combine with different vowel qualities, vowel lengths, and tones. In Agar Dinka, a contrast between creaky and breathy vowels is put forward (Andersen, 1987, 1993), while for Ageer Dinka, the contrast is characterised as modal compared to breathy (Remijsen, 2014), and the same is noted for Luanyjang Dinka, with additional comments that modal vowels may be perceived as brassy or creaky (Remijsen & Manyang, 2009). While some lowering of F1 has been noted for breathy vowels in Dinka varieties (Jacobson, 1980; Denning, 1989; Remijsen & Manyang, 2009), this does not appear to be as significant a cue as for ATR contrasts in other Nilotic languages. Where examples of differences in measures such as spectral slope have been provided, acoustic data support impressions of voice quality differences (Denning, 1989; Remijsen & Manyang, 2009). For the Bor variety of Dinka, four contrastive voice qualities are described: modal ('normal'), breathy, hollow (faucalised), and harsh (Denning, 1989), contributing to an extremely complex vowel system. From an investigation of the articulation of these four voice quality types using laryngoscopic techniques, Edmondson and Esling (2006) provide evidence that each has a distinct laryngeal configuration, drawing on changes in glottal adduction, ventricular incursion, aryepiglottic constriction, tongue and epiglottis retraction, larynx height, and lateral constriction in the pharynx. They also note that Dinka Bor is so far the only language in which faucalised voice is attested to have a contrastive function. Though the use of these voice qualities sets the vowel systems of languages such as Dinka apart from ATR-type systems in other Nilotic languages, there are articulatory parallels to be found in the way that all of the languages discussed so far depend on changes in the constriction of the lower vocal tract to create distinctions between vowels, as discussed further in 4.2. While modal and breathy voice qualities are produced with a relatively unconstricted laryngeal setting, the overall shape of the pharynx is adjusted, via laryngeal configuration, to give rise to both the expanded setting used for hollow voice and the types of constriction which co-occur with harsh phonation.

The other main point of interest regarding vowel phonation is the voiceless (also 'shadow') vowels which are described as contrastive for Eastern Nilotic languages in the Teso-Turkana group. In Turkana, Toposa, Karimojong and Ateso, any of the nine attested vowel qualities may occur as a voiceless vowel in word-final position (Dimmendaal, 1983b; M. Schröder & Schröder, 1987; Novelli, 1985; Schrock, 2014; Barasa, 2017). Researchers are unanimous that this is not a predictable process. In at least Toposa, the voicelessness seems to be most notable when words are produced in isolation, or prepausally, while the degree of voicing may vary in other contexts for a number of reasons, but without approaching that of the contrastive voiced vowels (M. Schröder & Schröder, 1987). Dimmendaal (1983b) suggests that in Turkana, voiceless vowels are more likely to occur with close vowel qualities, but that voiceless open vowels are also attested. In Karimojong, some examples of word-medial voiceless vowels are also noted (Novelli, 1985). The phonetic characteristics of the voiceless compared to voiced vowels appear not to have been investigated so far, nor their perceptual salience, and they are widely noted to be a topic requiring further research for Teso-Turkana languages.

2.3.4 Length

A striking feature of Nilotic vowel systems is the ternary length contrasts found in a number of languages. These are most characteristic of the Western Nilotic Dinka-Nuer group. Contrasts between short, mid and long vowels (or short, long and overlong vowels) have been described in detail for a number of Dinka varieties, such as Agar Dinka (Andersen, 1987). For the Luanyjang, Bor, and Ageer varieties of Dinka these descriptions are supported by analyses of vowel duration which show substantial and significant differences between the three length categories (Remijsen & Gilley, 2008; Remijsen & Manyang, 2009; Remijsen, 2013, 2014). Observations for Thok Reel similarly point towards a 3-way length contrast, and are similarly borne out by duration measurements (Reid, 2010). Nuer may also have three contrastive vowel lengths (Crazzolara, 1933; Gjersøe, 2016; Monich, 2017). Elsewhere in Western Nilotic, ternary contrasts appear to only be found in Shilluk (Remijsen, Miller-Naudé & Gilley, 2015). Other Northern Luo languages instead maintain a two-way length contrast between vowels (Andersen, 1989; Reh, 1996; Andersen, 2004, 1999b, 2007; Storch, 2014), including for diphthongs in the case of Mabaan (Andersen, 1999c). Among the Southern Luo languages, the status of vowel length differences is less certain; for Kumam, Acholi and Lango, long vowels are only found to occur in predictable environments as a result of phonetic or morphophonological processes, for example in final position, with contour tones, and via compensatory lengthening (Hieda, 2011, 2016; Noonan, 1992). For Dholuo, Tucker (1994) speculates that long vowels may be related to stress, while Swenson (2015) suggests length is phonemic, but not well understood.

There are no three-way vowel length contrasts among Southern Nilotic languages, but a two-way length distinction is found in most, if not all, languages of this family, though the functional load of the contrast may vary (Rottland, 1982, 1983; Zwarts, 2004; Creider & Creider, 1989; Local & Lodge, 1996; Toweett, 1979; Baroja et al., 1989). The status of vowel length distinctions across Eastern Nilotic languages seems more tenuous. For languages of the Bari group, no vowel length contrasts are described (Spagnolo, 1933; B. L. Hall & Yokwe, 1981; Stirtz, 2014a; Cohen, 2000; Onziga & Gilley, 2012). Among those of the Teso-Turkana group, vowel length differences do not appear to have been mentioned for Toposa (M. Schröder & Schröder, 1987; M. C. Schröder, 2004); for other languages, long vowels are proposed as contrastive by some researchers and interpreted as vowel sequences by others (Dimmendaal, 1983b; Novelli, 1985; Noske, 1996; Schrock, 2014; Barasa, 2017). For Maa varieties, impressions of contrastive vowel length are also noted (Tucker & Mpaayei, 1955; Heine, 1980; Vossen, 1982; Levergood, 1987), but have received little discussion, and are not mentioned in more recent research incorporating discussion of vowel contrasts (Guion et al., 2004; D. L. Payne, 2012; Quinn-Wreidt, 2013). For languages in the Lotuxo family, vowel length seems unlikely to have a significant contrastive function. For Otuho, Muratori (1938) notes the presence of long vowels, as well as sequences of identical vowels, but in subsequent work, Vossen (1982) observes that vowel length is not phonologically relevant in Otuho. Although Coates (1985) later proposes that Otuho does have long vowels, it is worth noting that many of the examples transcribed as long vowels have a falling tone. For Dongotono, Lokoya and Lopit, Vossen (1982) specifically notes that he finds no evidence of vowel length being a distinctive feature in these varieties. Similar conclusions are drawn by Turner (2001) for Lopit, and no mention of vowel length is made by Stirtz (2014b).

2.4 Nilotic Tone

2.4.1 Functions of tone

Of all aspects of Nilotic sound systems, tone is the most difficult to comprehensively review, for the simple reason that it has received far less attention in the descriptive literature on Nilotic languages, and Nilo-Saharan languages more generally. This likely has much to do with the range of morphosyntactic functions tone may have in these languages (Tucker & Bryan, 1966), as well as the various types of phonological processes which may apply. These possibilities, which interact with lexical uses of tone, add to the challenge of arriving at an analysis of tonal distinctions. Grammatical uses of tone are widespread among languages of Africa (Welmers, 1973), and there are no limitations on which functions may be performed using tonal phonology, compared to segmental and metrical phonology (Hyman, 2011). However, for many Nilo-Saharan languages, the various applications of tone remain under-described, and tone is often not marked in existing grammars and dictionaries. For that reason, and given the focus of the present work, a detailed survey of the grammatical functions of tone in Nilotic languages is beyond the scope of this chapter, but from the sources discussed in the preceding sections, it can be seen that tone is used to mark a wide range of grammatical distinctions including noun case, number, person, tense, aspect, mood, and many others. For some Nilotic languages, tone appears to have a greater grammatical than lexical functional load; for example, for Eastern Nilotic Maa, Tucker and Mpaayei (1955, p. 16) note that tone is important both grammatically and lexically, but that there are few examples of lexical distinctions made by tone alone, and Rasmussen (2002, pp. 22–24) argues that, within the Maa verbal system, the function of tone is entirely grammatical, and it is not used for any lexical distinctions. However, the extent to which tone is used in the grammar varies from language to language, and in some cases, such as for the Western Nilotic language Belanda Boor, tone appears to have no grammatical function at all (Von Heyking, 2013).

2.4.2 Tone levels and basic contrasts

Following Pike (1948), tone systems are often described as being either ‘register systems’, in which tonal distinctions are based on the relative pitch of a number of level tones, and any contours which arise can be derived from these level tones, or as ‘contour systems’, in which distinctive rising and falling trajectory shapes within the tonal space are considered basic to the system (see 6.2.1 for further discussion). Register systems are widely attested among languages of the African continent (Clements & Rialland, 2008, pp. 70–74), with two tone levels being most common (Wedekind, 1985). However, striking diversity can be found within the tone systems of the Nilotic family alone, and a number of typologically interesting findings have emerged in recent work. Given that the level of description varies across Nilotic languages, and that tonal descriptions are sometimes couched in different theoretical approaches, it is not always clear how many distinctive ‘tonemes’ a language has, but from available data it is apparent that languages of the Western Nilotic family tend towards larger tonal inventories than languages of the Eastern and Southern Nilotic families. However, the stem-internal morphology characteristic of these languages, which includes alternations of tone, vowel quality, voice quality, and vowel length, further compounds the challenges to tonal analyses.

For Nuer, previous work includes a range of proposals for the tonal inventory, or suggests no contrastive tones at all (Crazzolara, 1933; Yigezu, 1994; Frank, 1999), but research underway points towards High and Low level tones, and a High-Low falling tone, and is supported by phonetic results demonstrating fundamental frequency as a correlate to these (Gjersøe, 2016, 2017; see also Baerman, Monich & Reid, 2016). For Thok Reel, also in the Dinka-Nuer group, similar observations of High, Low and a High-Low falling tone are made (Reid, 2010), supplemented by examples showing the f0 characteristics of these tones. For Agar Dinka, Andersen (1987) proposes High, Low, and High-Low falling tones, with a range of phonetic realisations including a high followed by low-level trajectory for the Low tone in some contexts, compared to the high level followed by low trajectory for the High-Low falling tone. The possibility of Low and high-low Falling tone realisations with a similar shape, but with differences in timing, is also noted for Luanyjang Dinka (Remijsen & Ladd, 2008, p. 181), which additionally has a fourth, low-high Rising tone (Remijsen & Ladd, 2008; Remijsen & Manyang, 2009). The descriptions of High, Low, high-low Falling and low-high Rising tones in Luanyjang Dinka are accompanied by acoustic evidence for the contrasts, and a range of context-sensitive f0 modifications. Bor varieties of Dinka are attested to all have Low, High, Mid and Fall tone categories as contrastive, and the detailed explorations of their realisations by Remijsen (2013) show that these tones differ in the level and shape of the fundamental frequency trajectory as well as in tonal alignment. Outside the Dinka-Nuer group, the only other Western Nilotic language which has been the subject of detailed phonetic as well as phonological analyses of tone is Shilluk, which may also be the most tonally complex of the Nilotic languages. While previous work suggests contrastive High, Low and Mid level tones, with a range of contour tones arising from combinations of these (Westermann, 1912; Gilley, 1992), in more recent research, eight contrastive tones are explicitly set out, with accompanying phonetic evidence (Remijsen et al., 2011; Remijsen & Ayoker, 2014). These comprise Low, Mid and High level tones, and contour tones including a Rise, and four falls: an Early High Fall, Late High Fall, and High Fall to Mid, all with an initial target of comparable height to the High level tone, as well as an Early Low Fall, with an initial target corresponding to the height of the Mid level tone. Tone realisation in Dinka and Shilluk is discussed further in 2.4.3.

Elsewhere in the Northern Luo group of Western Nilotic, fewer contrastive tones are more typical. Both Jumjum and Kurmuk are described as having High and Low level tones and a High-Low falling tone (Andersen, 2004, 2007), while Mabaan has a High, Low, a High-Low falling tone and a Low-High rising tone (Andersen, 1999c). Andersen (1988b) proposes an analysis of just High and Low tones for Päri (though an analysis with a Mid tone was also explored), while for Anywa, Reh (1996, p. 45) tentatively suggests High, Low, Rising and Mid tones. For Belanda Boor, High, Mid and Low level tones are proposed, as well as contours which appear to include at least rising and falling tones (Von Heyking, 2013). In the Southern Luo group, a similar range of tones is observed. For Dholuo, suggestions by Tucker (1994), amidst a detailed explanation of the challenges to identifying tonemes and their allotones, seem to indicate at least High and Low level tones, and High-Low falling and Low-High rising with some contrastive function, and various phonetic realisations of these. For Alur, early impressions suggest High, Low, and Mid tones, and various possible contours (Ringe, 1948). Lango has been shown to have High, Low and Falling tones, as well as a Rising tone with limited distribution (Noonan, 1992), and Hieda (2010) reports High and Low level tones, plus Falling and Rising tones with limited distributions for Kumam, and for Acholi, similarly finds High and Low level tones, a Rising tone with a low functional load, and a Falling tone resulting from phonological processes (Hieda, 2016).

Among the Southern Nilotic languages, the tone systems are generally described as having two to four contrasts. For the Kalenjin group of languages, Creider (1982) observes that those in the immediate Rift Valley (Nandi-Markweta) group all have High, Low and Falling tonemes, and indeed this is what has been noted elsewhere for Endo (Markweta) (Zwarts, 2004) and Kipsikis (Hieda, 1982; Tucker & Bryan, 1964), though for Tugen, Jerono (2011, p. 36) suggests only High and Low level tones as contrastive. For Nandi, Creider and Creider (1989) observe contrasts between High and Low level tones as well as a High-Falling tone, and a range of phonetic realisations of these, including a Low-Falling tone. Earlier work proposed additional Mid and Mid-Falling tones (Tucker & Bryan, 1964). Creider (1982) suggests, through comparison with other Kalenjin languages, that Nandi has the most complex tonal system of the Kalenjin languages. For the Kalenjin varieties in the immediate Mt. Eldon (Sabaot) group, Creider (1982) notes that Terik has preserved the same High, Low and Falling contrast characteristic of the Kalenjin languages, but that in Pok and Pong'om the High and High-Falling tones have merged, leaving a contrast between only High and Low level tones. Another Kalenjin variety, Akie, is proposed to have contrasts between High, Low, High-Falling and Low-Falling tones (König, Heine & Legère, 2015). For Pökoot, early work suggests High, Mid, and Low tones and a range of contours drawing on these (Crazzolara, 1978), but later observations state either High, Low and Falling tones (Creider, 1982) or High, Low, High-Low, and Low-High tones (Baroja et al., 1989). An inventory of Low, High, and Falling tones is also found in Datooga (Rottland, 1983). So far, there appear to be no phonetic investigations of tone in any Southern Nilotic languages.

In the Eastern Nilotic family, various tonal inventories have been observed, and observations are broadly similar to those for the Southern Nilotic family. Among the Bari languages, High, Low, Mid, and High-Falling tones have been suggested for Bari itself Vossen (1982, p. 173), though in a later detailed study, Yokwe (1987) posits only Low, High and Falling. For the varieties Kakwa, Kuku, Mundari, Nyanggwara, Ngyepu and Fujulu in the immediate Bari language family, High, Low, Mid, and High-Falling tones have been described (Vossen, 1982, p. 178), but more recent work for Kuku, Kakwa and Mundari finds evidence for only High, Low and Falling tones, with the Falling tone analysed as a sequence of High and Low in some cases, and noted as word-final only in Mundari (Cohen, 2000; Onziga & Gilley, 2012; Stirtz, 2014a). Among the non-Bari languages, detailed descriptions of tonal patterns can be found for some language varieties in the Ongamo-Maa subfamily, though as is true across Nilotic languages, much work remains to be done. In their grammar of Maasai, Tucker and Mpaayei (1955) dedicate a full chapter to a detailed discussion of Maasai tone, in a departure from the tradition of many other early Nilo-Saharan grammars to acknowledge tone in no more than a token way. They state that Maasai has the level tones High, Mid and Low, and an additional Falling (High-Low) tone, though they note that the Mid tone really represents an allophone of both the High and Low tones (1955, pp. 167-170). Vossen (1982, p. 198) puts forward the same four tones. However, the Mid tone does not feature in more recent descriptions, for example by Levergood (1987) and Rasmussen (2002). Both researchers describe contrastive High and Low level tones, as well as a High-Low falling tone which is limited to word- or phrase-final position, a restriction which leads Rasmussen (2002, pp. 20–21) to interpret it as non-contrastive. The mora is argued to be the tone-bearing unit in both of these studies. For the northern Maa varieties Camus and Samburu, three distinct tones are attested: High, Low, and High-Falling (Vossen, 1982, p. 201, Heine, 1980, p. 103). No mention is made of a Mid tone.

In the Teso-Turkana group, the patterns are similar again. For Ateso, Karimojong and Toposa, proposed tonal inventories include at least High and Low level tones and a High-Low falling tone, often word-final and typically analysed as a High-Low sequence ((Barasa, 2017); Vossen, 1982, pp. 180–181; Novelli, 1985, pp. 37–39; H. Schröder, 2008, p. 3). Various phonetic contours, and a phonetic Mid tone, are noted in some cases. Of the Teso-Turkana languages, Turkana is perhaps the best-described, though tonal analyses have varied. Contrasts between either 3 level tones or 2 level tones and a Falling tone have been suggested, , but in Dimmendaal's (1983b) comprehensive treatment of tone in Turkana, an analysis of just two tonemes, High and Low, is presented. Various tonal processes are discussed in detail to account for additional phonetic tones. Dimmendaal (1983b, p. 40) observes that Falling tones do occur on long vowels, but as noted in 2.3.4, these are analysed as vowel sequences, rather than contrastive vowel length, and therefore the tones are presumably interpreted as sequences of High and Low tones. In the Lotuxo family, tonal investigations have been limited. In his grammar of Otuho, Muratori (1938) notes the presence of distinctive tone patterns but does not investigate these, nor mark tone throughout the grammar. Vossen (1982, p. 189) records High, Low, Mid, and High-Falling tones in his wordlist data for Otuho, and in more detailed discussion from Coates (1985, p. 102), it is suggested that there may be "three or four level tones, and several glides which may be either rising or falling". The transcription used in the study indicates High, Mid and Low level tones, and High-Falling and Mid-Falling contour tones. For Dongotono, Lokoya and Lopit, Vossen (1982) records High, Low, Mid and High-Falling tones, as for Otuho. In Turner's (2001) phonology sketch of Lopit, he proposes two contrastive level tones, High and Low, and also notes the presence of Falling tones. In recent work on Lopit by Stirtz (2014b, p. 16), High and Low level tones are similarly observed, as well as a Falling tone (analysed as a sequence of High and Low). The syllable is proposed as the tone-bearing unit. Stirtz (2014b) notes that the Falling tone is common on word-final syllables, but rare in other word positions. He also notes the presence of a rare Rising tone.

2.4.3 Status and nature of contour tones

The above overview shows that there is a great deal of uncertainty regarding the tonal inventories of many Nilotic languages, and that much of this relates to the status of perceived pitch differences, especially where contour tones are concerned. As noted in 2.4.2, for languages described as having 'contour systems', particularly those of East and Southeast Asia, tones with dynamic rising or falling pitch patterns are generally assumed to be discrete units, whereas for African languages, which are typically characterised as having 'register systems', contour tones are most often interpreted as sequences of level tones attached to a single tone-bearing unit (Pike, 1948). There is a large body of phonological evidence, particularly drawing on data for Niger-Congo languages (e.g. Clements & Goldsmith, 1984), showing that contour tones can very often be derived from level tones in the tone inventory of a given language. Contours may arise as positional variants of a level tone, or via morphophonological processes which permit two level tones to share a syllable (or mora) (Odden, 1995; Yip, 2002, pp. 130–170; Clements, 2000, pp. 152–158). Observations of African tone patterns, particularly relating to tonal mobility, have significantly influenced phonological theory (Hyman, 2003), specifically the development of autosegmental and metrical theory (Goldsmith, 1990), and continue to inform analyses of tone in African languages. However, even where specific phonological processes resulting in falling tones are not explicitly discussed (for example in the early stages of phonological description), perceived contour tones are very often described as sequences of level pitch targets, perhaps because the evidence that they can be decomposed into level tones is so strong that the decomposition is often taken for granted (Odden, in press). Some authors caution against assumptions that contour tones are necessarily decomposable, emphasising that sufficient language-internal evidence, informed by the rich typology of tone systems worldwide, must be the basis of such analyses, and noting that it is equally reasonable to adopt the standpoint that contours are not decomposable unless there is positive evidence to the contrary (Michaud & Vaissière, 2015, pp. 44–53).

The necessary level of evidence is not available for all Nilotic languages, but phonological and phonetic analyses discussed in 2.4.2 indicate various possibilities for the status of contour tones in Nilotic languages. In some cases researchers make it clear that they do not yet have sufficient evidence to draw conclusions, but in others, falling and rising tones are specifically noted as positional variants, analysed as the result of morphophonological processes which cause tone sequences, or simply described as sequences of high and low level tones without further qualification (leaving the question of their phonemic status open). However, for a number of Nilotic languages, there is clear evidence for phonemic contour tones, such as in various Western Nilotic languages discussed in 2.4.2. Where this evidence includes phonetic analyses, results both provide quantitative support for perceived tone categories and offer significant typological insights. For example, for Shilluk, Remijsen and Ayoker (2014) demonstrate that the distinction between two High Falling tones proposed to be contrastive hinges on the timing of the fall in f0 values; the tones do not differ in f0 height, the size of the change in f0, or duration, but only in tonal alignment. Given existing views that tonal alignment is not used to contrast contour tones (e.g. Hyman, 1988a), this has implications for the crosslinguistic understanding of how languages maintain tonal distinctions, particularly in a crowded system such as the 8-tone inventory described for Shilluk. The importance of tonal alignment is also noted for Dinka, and shown to be the primary difference between the Falling tone and a high-falling allophone of the Low tone (Remijsen, 2013). Both studies also show that distinctions in tonal alignment are maintained regardless of vowel length (recalling that both languages have a 3-way vowel length distinction). Findings of this sort show the value of pursuing phonetic evidence as part of establishing the bases of tonal contrasts, and demonstrate that the crosslinguistic understanding of tone will benefit from more empirical data on tone realisation, particularly for African languages.

2.4.4 Other prosodic considerations

Phonetic variants of contrastive tones have only been mentioned in passing in a few examples above, but are also important to consider, partly because these contribute to a more comprehensive description of the sound system, but also because, to a greater extent than vowel and consonant allophones, tonal variants may interact with grammatical patterns. However, detailed discussions of allophonic variation are beyond the scope of this chapter, and when it comes to Nilotic tonal variants, information is particularly scarce. As noted above, the status of observed tones is not always clearly established in available descriptions. However, a number of studies explicitly address not only the contrasts, but also include some observations on local and global effects on tone. For several Western Nilotic languages, such as Kumam, Acholi, Lango, Dholuo, Päri, and Thok Reel, various processes including downstep, downdrift and tone sandhi have been described (Hieda, 2010; Hieda, 2016; Tucker, 1994, pp. 43–63; Noonan, 1992, pp. 49–65; Andersen, 1988b; Reid, 2010). Some of these are found to be sensitive to morphosyntactic context, for example in Dinka (Andersen, 1987; Remijsen & Ladd, 2008), and for Shilluk, while some patterns of tone sandhi are noted, Remijsen and Ayoker (2014) find that a general characteristic of the Shilluk tone system is the phonological stability of underlying tonal specification. There is less description of tonal variants for languages elsewhere in the Nilotic group, though analyses of Nandi and comparisons across the Southern Nilotic Kalenjin group include observations of various contextual effects on tone realisation (Creider, 1982; Creider & Creider, 1989), and some relevant remarks can be found in descriptions of tone in Eastern Nilotic languages such as Bari (Yokwe, 1987), Turkana (Dimmendaal, 1983b), and Maa varieties (Tucker & Mpaayei, 1955; Levergood, 1987; Rasmussen, 2002).

Only in a small number of cases have the possible functions of different intonation patterns been explored for Nilotic languages, and this is an understudied topic for African languages more generally (though see e.g. Downing & Rialland, 2016). For Western Nilotic Luo, Creider (1978) examines the structural properties of intonation units corresponding to declarative, interrogative and sustaining (continuation) utterances, and their use in interaction. Karan and Pike (1984) similarly offer some observations on intonation patterns in Southern Nilotic Koony which correspond to questioning and calling utterances, as well as those signalling 'lack of interest'. For Arusa Maa, in the Eastern Nilotic family, Levergood (1987) notes particular intonational patterns occurring with declarative statements and yes/no questions respectively. Later work by Baltazani (2002) includes a preliminary description of Maa intonational phonology, with specific reference to patterns for declarative and interrogative utterances, and also explores the interactions between intonation and case-marking, which as noted above is indicated by tone changes on the noun. This appears to so far be the only work examining Eastern Nilotic tone realisation with reference to phonetic data. A particularly interesting finding is that although the changes in fundamental frequency according to different intonation patterns may to some extent mask the fundamental frequency characteristics of case-marking tones, amplitude cues remain. This suggests that acoustic cues other than fundamental frequency are worth examining in analyses of Nilotic tone. However, it is at the same time clear that the level of description for many Nilotic languages needs to be vastly improved before comprehensive phonetic studies of tone and intonation can be undertaken.

Some descriptions of Nilotic languages mention word-level stress, or accent, in addition to tone, though likely with reference to a range of perceived phenomena. In their overviews of linguistic features for Western, Eastern and Southern Nilotic languages, Tucker and Bryan (1966) make passing mention of stress occurring on verb stems, possibly associated with vowel length in some cases (1966, p. 409), and not always easy to separate from tone (1966, p. 450). For the Southern and Eastern Nilotic languages, there is little mention of this possibility in later descriptive work, apart from some explicit statements that there is no contrastive stress, for example for Turkana (Heine, 1980, p. 44) and Otuho (Coates, 1985, p. 102). However, observations of stress can be found in some more recent descriptions of Western Nilotic languages; for Alur, Lango and Dholuo, stress is impressionistically perceived for the first root vowel of a word (Heusing, 2006; Noonan, 1992, pp. 42–43; Tucker, 1994, pp. 18–19). Noonan (1992) describes stressed vowels as being somewhat louder and slightly longer than unstressed vowels in Lango, and Tucker (1994, pp. 18–19) notes that Dholuo stress occurs with longer vowels in some contexts, for speakers of some dialects (and appears to imply that loudness is otherwise the percept). In none of these cases is stress suggested to be contrastive, and transcribed examples show it to occur with a range of tones. For both Shilluk and Dinka, Gilley (2004) proposes the existence of stress, with a distinctive function (including for a range of grammatical contrasts), perceived to be correlated with shorter (not longer) vowel durations, and higher intensity. Given that in both languages, words are typically monosyllabic, stress is presented as an additional parameter of phonological contrast within the syllable, rather than in the more usual sense of metrical prominence. More recent work demonstrates that perceived differences are instead attributable to the three degrees of vowel length and a contrast between High Falling and Falling tones (Remijsen et al., 2011). Recent quantitative work on Dinka varieties does not mention any feature of stress in the sense used by Gilley (2004), but, as for Shilluk, demonstrates the evidence for other suprasegmental complexities (e.g. Remijsen & Manyang, 2009). Other work investigating prominence in Dinka postulates various patterns applying at the utterance level (Norton, 2014).

2.5 Discussion of Aims and Research Questions

The aim of this project, and the questions which guide the research, were briefly introduced in 1.5.2. In light of the typological overview presented in the preceding sections of this chapter, and in order to lead into the presentation of research findings which begins in the following chapter, these are returned to here with some further detail. The primary aim of the project is, as stated in 1.5.2, to produce a phonetically-based description of the phonology of Lopit, by first developing hypotheses about the segmental and tonal inventory of Lopit based on collected lexical and morphosyntactic data, then using experimental approaches to test the evidence for three phenomena of particular typological interest. In 1.5.1, a general observation was made that there is a need for the description of African languages to be improved by more phonetic data, particularly relating to features of typological interest, and particularly for minority languages which have received less scholarly attention. The overview of Nilotic sound systems which has been presented in this chapter further demonstrates this need; for many languages, there is uncertainty about the nature and status of consonants, vowels and tones described in impressionistic work, and very few phonetic investigations have taken place across the language family. Given that the phonological properties of these languages include a number of typologically interesting characteristics, some of which are not well-understood crosslinguistically, there is clear scope to improve not just the level of detail in the linguistic record for Nilotic languages, but to inform wider questions about the structures and properties of the world's languages. The research questions below relate to Lopit, which has been selected as the focus of the present work, but would apply equally well to other Nilotic languages, particularly of the Eastern Nilotic group.

2.5.1 Phonological contrasts

RQ1: What are the major phonological contrasts in Lopit?

The first research question, RQ1, is a general one, motivated by the need to clearly establish the inventory of consonant, vowel and tone phonemes in Lopit. At the outset of this work, some observations on Lopit phonology were available, and others have emerged concurrently, but these have been limited by the amount of data collection and testing able to be undertaken (Driberg, 1932; Turner, 2001; Stirtz, 2014b). The extended fieldwork planned for this project offers an opportunity to make a significant contribution to the understanding of Lopit phonology via a substantial amount of data and accompanying analyses. From the preceding overview, some specific points arise which warrant particular attention. While the available data for Lopit, and other Eastern Nilotic languages, points towards a reasonably uncontroversial set of place contrasts (though with uncertainties regarding the status of the final glottal stop), the status of fricatives in relation to corresponding voiceless stops is not entirely clear, as is the extent to which length, or strength, is used to form contrasts across the consonant inventory. There are also inconsistent findings surrounding the number of monophthongs in the vowel system, and whether they are in part distinguished by the phonological feature [ATR] (which may also be used in harmony processes). Furthermore, there are different views regarding the number of tones used for lexical and grammatical distinctions. RQ1 is the main focus of analyses presented in the following chapter, Chapter 3.

2.5.2 Acoustic properties of vowels

RQ2: What are the acoustic correlates of vowel contrasts found in Lopit?

RQ2 is the first of four specific research questions, which follow on from the analyses undertaken in relation to RQ1. As noted in 2.3.2, existing observations on Lopit phonology include different proposals for the number of monophthongs in the vowel system (5, 9 or 10), and whether the feature ATR has relevance in Lopit phonology. Acoustic analyses will provide quantitative insights into the Lopit vowel space, and provide supporting evidence for or against the impressions put forward in Chapter 3. More specifically, however, analyses relating to this question aim to determine whether the acoustic bases for selected vowel contrasts have similarities to crosslinguistic findings for the acoustic correlates of 'Advanced Tongue Root' contrasts (e.g. as surveyed by Casali, 2008, and discussed in more detail in 4.2). Results relating to RQ2 will provide the first acoustic data for vowels in Lopit, and join a small number of existing acoustic studies of vowel systems in Eastern Nilotic languages (Lindau, 1975; Guion et al., 2004) and the wider Nilotic family (e.g. Jacobson, 1978; Denning, 1989, Remijsen & Gilley, 2008, Remijsen et al., 2011). RQ2 is one of two investigated in Chapter 4, according to specific hypotheses developed for testing (three of the four hypotheses presented in 4.3 relate to this question). Acoustic measures of interest include the frequencies of the first three formants, duration, and spectral emphasis.

2.5.3 Articulatory properties of vowels

RQ3: What sorts of articulatory mechanisms are involved in producing Lopit vowel contrasts?

RQ3 is closely tied to RQ2. As noted in 2.3.1 and discussed further in 4.2, the correlates of ATR contrasts have been the subject of much discussion in the phonetic and phonological literature. It has been observed that while there are some crosslinguistic patterns in the acoustic characteristics which appear to be most relevant for ATR contrasts, such as differences in F1, others appear to be language-specific, and articulatory investigations have shown that even where an acoustic correlate appears to be shared by different languages, the articulatory strategy used to produce it may vary. The articulation therefore cannot be assumed on the basis of acoustic data. Given that it has been speculated that speakers of Nilo-Saharan languages may use more variable strategies, drawing on changes in both tongue body height and tongue root position, to implement putative ATR contrasts (e.g. Lindau et al., 1972; Jacobson, 1978), the investigation of articulatory as well as acoustic correlates of possible ATR distinctions is particularly relevant for Lopit and related languages. More generally, the results will inform the wider question of the relationship between changes in position of the tongue root and the use of ATR as a phonological feature. Results relating to RQ3 will provide the first articulatory data pertaining to Lopit vowels, using ultrasound tongue imaging to complement the small amount of earlier radiographic work undertaken for some other Nilotic languages (Lindau et al., 1972; Jacobson, 1978). RQ3 is the second question investigated in Chapter 4, with reference to one of the four hypotheses listed in 4.3.

2.5.4 Phonetic properties of glides

RQ4: What are the phonetic characteristics of contrastive glides in Lopit?

RQ4 relates to the length contrasts proposed by various researchers to distinguish a number of consonants of the same place, manner and voicing in Lopit, including palatal and labial-velar glides. Length (or strength) contrasts in the consonant inventory have been noted for a number of Eastern Nilotic languages, as discussed in 2.2.4, though for some, such as Maa, these appear to apply only to glides, while in the immediate Lotuxo family, they may also apply to consonants at other manners of articulation. The possibility of distinctive glide length is of particular interest, given that geminate glides are typologically uncommon (Maddieson, 2008) and thought to pose a perceptual challenge (Kawahara, 2007). For these reasons, establishing whether there is indeed a contrast between glides at the same place of articulation, and the phonetic nature of the contrast, is of value both as part of analysing the sound system of Lopit, but also to inform crosslinguistic understandings of how such contrasts may be implemented. As yet, length/strength contrasts among glides have not been subject to phonetic investigation in Lopit or any Eastern Nilotic languages (or Western Nilotic languages which have geminate consonants at least as the result of morphophonological processes), and have only been studied for a small number of languages spoken elsewhere in the world. RQ4 is investigated in Chapter 5, following the three hypotheses listed in 5.3. Phonetic measures of interest include the duration of glides and preceding vowels, frequencies of the first three formants, and RMS amplitude.

2.5.5 Phonetic properties of tones

RQ5: What are the phonetic characteristics of lexically contrastive tones on nouns in Lopit?

RQ5 explores tonal distinctions, which in Lopit are suggested to be used for both grammatical and lexical contrasts (Moodie, in progress). Given that the range of grammatical functions of tone in the verbal morphology appears to be complex, and are still being investigated, this question focuses only on the realisation of tone in nouns, for which grammatical uses of tone are better understood at this stage. However, there is no suggestion that the tonal categories in Lopit differ for nouns compared to verbs. In existing work on Lopit, all researchers observe High, Falling and Low tones, which as shown are fairly characteristic of Eastern Nilotic languages, but as noted in 2.4.2, there are additional suggestions of a Mid and a Rising tone. Analyses pertaining to this question will therefore assess the phonetic evidence for tone contrasts proposed in Chapter 3. While the phonetic realisation of tone in African languages is assumed to be more crosslinguistically straighforward than ATR contrasts or long/strong glides, with contrasts signalled by differences in fundamental frequency, it has received little attention, particularly for Nilo-Saharan languages. As discussed in 2.4.3, phonetic investigations of tone in some Western Nilotic languages, such as Dinka (Remijsen, 2013) and Shilluk (Remijsen & Ayoker, 2014), have revealed patterns which prompt some reconsideration of the typology of tone systems crosslinguistically, as well as for assumptions relating to African languages in particular. Though Eastern Nilotic languages are less tonally complex, there is clearly value in improving the amount of empirical data available relating to tone production in Nilotic languages. RQ5 is the focus of Chapter 6, and is explored with reference to the two hypotheses listed in 6.3. Acoustic measures of interest include fundamental frequency and RMS amplitude (between which there is a link, as discussed in 6.2), as well as duration.

2.6 Chapter Summary

This chapter has provided an overview of segmental and tonal phenomena in Nilotic languages, outlining the main phonological patterns found in Western, Southern and Eastern Nilotic languages and highlighting features of particular interest. In particular, the details relating to Lopit and other Eastern Nilotic languages provide essential background to the analyses contained in the remainder of this thesis, and demonstrate some of the phonetic and phonological questions which are have not yet been resolved for many of these languages. As the overview shows, some of these questions, for example relating to the phonetic implementation of vowel contrasts, are common across all three branches of Nilotic. While phonetic analyses of consonant, vowel and tonal have been undertaken for some Nilotic languages, and have been mentioned in the relevant sections, it is clear that there is enormous scope to expand on the understanding of the acoustic, articulatory and perceptual correlates of Nilotic speech sounds, and that there are valuable insights to be gained from doing so. Furthermore, it is apparent that for a number of Nilotic languages, insufficient work has taken place to provide a comprehensive proposal and accompanying evidence for the main phonological contrasts, without which, it is difficult for phonetic investigations to proceed. For Lopit, this is taken up in the following chapter, Chapter 3, in which a series of consonant, vowel and tone contrasts are put forward based on analyses of lexical and morphosyntactic data collected in the course of this project.

Chapter 3
Lopit Phonology

3.1 Introduction

Following the overview of Nilotic sound systems presented in Chapter 2, this chapter turns to a description of Lopit phonology based on data collected as outlined in 1.6.2 and discussed in more detail in 3.2, below. The broad aim of this chapter is to formulate hypotheses regarding the inventory of phonemes in Lopit, as well as phonotactics and key phonological processes, in order to address RQ4, "What are the major phonological contrasts in Lopit?". Data presented here are for the Dorik dialect of Lopit, unless otherwise noted, but brief comparisons with existing work on Lopit are made throughout, recalling that other studies focused primarily on the southern (Turner, 2001; Vossen, 1982) and central (Stirtz, 2014b) dialects. 3.3 details the consonant inventory of Lopit and notes some phonological processes applying to consonants, and 3.4 introduces Lopit vowel phonemes, and discusses vowel harmony and assimilation processes. 3.5 focuses on tone, first through a discussion of tonal contrasts used for lexical distinctions, followed by a summary of some of the grammatical functions of tone, and 3.6 then provides an overview of the word and syllable structure of Lopit. 3.7 contains a brief summary of the observations on the phonology of Lopit, and points towards some features which are of particular interest for further exploration using experimental approaches. Extended discussion comparing Lopit phonetics and phonology to that of other Nilotic languages (including others in the Lotuxo family) and to wider crosslinguistic patterns is reserved for Chapter 7, though some relevant points are also noted in the intervening experimental chapters.

Lexical data showing examples of consonant, vowel and tonal contrasts are presented in tables in the relevant sections, and supplemented by additional data throughout the chapter. Examples drawn from fieldwork data are provided in broad phonetic transcription based on auditory impressions as well as inspection of spectrograms. The transcription of vowels includes any harmony and assimilation processes present in a given example; these are discussed in 3.4.3. Other phonological processes and instances of phonetic variation are noted for specific segments and words throughout. Tone is transcribed using the phonemic tone categories discussed in 3.5. Each of the approximately 500 examples is followed by a superscript letter, or sequence of two letters, which corresponds to an entry in Appendix B listing the identifier for the recording from which the example is drawn, and the relevant time point. In many cases, the specific recording reference provided is arbitrarily chosen, given that most examples are of words which have been checked many times, with multiple speakers.

While this is not a crosslinguistic or cross-dialectal study, occasional reference is made to lexical data collected by other authors for Lopit and closely-related languages. In such cases, the source is noted in the text as well as in Appendix B. For clarity, lexical examples from other sources are presented in angled brackets < > and are also followed by initials noting the source: CM indicates Muratori (1948), RV indicates Vossen (1982), HC indicates Coates (1985), DT indicates Turner (2001), and TS indicates Stirtz (2014b). As in Chapter 2, transcriptions are presented as they are in the original work except in cases where they depart from the conventions of the International Phonetic Alphabet. For examples drawn from data for the present study, nouns are given in the absolutive case unless otherwise indicated, and most verbs given are in simple person inflections, infinitive forms, or imperative forms. Some basic grammatical information follows each gloss. Further information on Lopit morphology and syntax can be found in Moodie (in progress) and associated work noted in 1.4.3.

3.2 Methodology

3.2.1 Participants

As noted in 1.6.1, analyses presented in this chapter are informed by data collected with thirteen adult Lopit speakers residing in Melbourne, and representing multiple dialects, and some additional reference has been made to audiovisual and written materials collected by others with Lopit speakers living in Kenya and South Sudan. However, the Dorik dialect of Lopit emerged early on as a particular focus, both because of the availability of speakers of that dialect and the practical need to narrow the focus to one dialect in the face of quite substantial dialect variation (which would pose a particular challenge in the experimental work building on these analyses). Dialect differences became quickly apparent in the early stages of this research; speakers are very aware of the characteristics of different Lopit dialects, and frequently pointed out lexical and pronunciation differences as they arose. Various differences were also observed compared to data recorded by Vossen (1982) with a speaker from the central part of the Lopit mountains, and by Turner (2001) with speakers mainly from the central and southern regions. It is worth noting that some of the Lopit speakers who migrated to Melbourne were among those who worked with Turner in Kenya, including one of his primary consultants, and this allowed me to verify some instances in which observable differences in word forms were attributable to differing dialect backgrounds of speakers. Later work by Stirtz (2014b) provides further evidence for a range of dialect differences.

3.2.2 Materials and elicitation

Given that the linguistic record of Lopit was very limited at the outset of this project, as described in 1.4.2, this project began with a large amount of lexical data collection, before moving into the exploration of phonological and morphological patterns. In the earliest stages of the project, the focus was on eliciting basic vocabulary. This was guided by various materials, such as a modified version of a 200-item Swadesh list (Swadesh, 1952, 1955). As an example of the types of data collected in the early stages of this project, the

Swadesh list for the Dorik variety of Lopit is shown in Appendix C (Table C.1). Swadesh lists were developed as a standard set of 'basic' words that are likely to occur in all languages, and are widely used by linguists; data collected using these types of wordlists is a useful starting point when language data are limited, and allows comparisons with similar lists for other languages. The content of the Swadesh list has some overlap with lexical data collected by Driberg (1932) and Vossen (1982) in early work on Lopit; additional items listed in those works were also referred to (and later, some examples from work by Turner (2001)). Other similar types of materials drawn on in this stage include the much longer SIL Comparative African Wordlist (Snider & Roberts, 2004), which includes items arranged by semantic domains (and therefore also offers inspiration for wide-ranging discussion topics), the detailed list of semantic domains created as part of the Dictionary Development Program (Moe, 2004; Shore & van den Berg, 2006), and available dictionaries and other sources of lexical data for languages closely related to Lopit (e.g. Muratori, 1948; Tucker & Mpaayei, 1955; Vossen, 1982; Dimmendaal, 1983b).

Common phrases and expressions were also elicited, based on participant intuitions as well as various phrasebook-style materials, and further collection of lexical data covered a range of topics, partly guided by the interests and expertise of the participants. Topics included animal and plant species of the area (with reference to field guides on these topics), foods and cooking, music and dancing, bush medicine, beekeeping, and cattle. The collected data included a range of narratives, for example procedural descriptions of drum-making and sorghum grinding, discussions of marriage traditions, hunting, and blacksmithing, and various children's stories. Phonological and morphological patterns emerging in the course of this data collection were queried and tested further in targeted elicitation sessions. Some of these sessions also included the elicitation of minimal or near-minimal pairs, based on speaker intuitions regarding words with similar combinations of sounds, as well as testing examples of these which arose in other sessions or were volunteered by different individual speakers. Lexical data were recorded in a database, which at the time of writing contains over 2,500 entries. A great many more have arisen in the course of elicitation and narrative collection, but have not yet been entered.

3.2.3 Recording procedures and data management

3.2.3.1 Audio recording

Regular recording sessions took place, sometimes with groups or pairs of speakers, but for the most part with individual speakers. Most of these were held in a quiet room in homes in Melbourne's south-east, both for the convenience and comfort of the participants and to allow greater flexibility in scheduling sessions. Some early sessions took place in a meeting room at the South Eastern Migrant Resource Centre in Dandenong, and other locations were occasionally used. Recordings collected during this stage of the project were made with a Zoom H4N portable audio recorder, at a sampling rate of 44.1kHz and 16-bit depth, and metadata accompanying each session was recorded in a spreadsheet. Some examples presented in this chapter are also drawn from later experimental data collection, following recording procedures outlined earlier in 1.6.3 and in each of the three following chapters. As noted earlier, where examples are given, these are followed by a superscript letter or letter sequence corresponding to an entry in Appendix B which identifies which recording each example is drawn from.

3.2.3.2 Transcription

Selected portions of the recorded data were transcribed in Praat (Boersma & Weenink, 2016), in the case of materials closely focused on the production of particular words and speech sounds, and Elan (Wittenburg, Brugman, Russel, Klassmann & Sloetjes, 2006; The Language Archive, 2016), in the case of narratives and extended discussions. For the most part, transcriptions made at this stage of the project were at the word level, using both broad phonetic transcription and the working orthography established for use in this project. The time-aligned transcriptions allow the content of the recording sessions to be easily searched and referred to, and as noted above, the recording identifier and time point for each example presented in this chapter is contained in Appendix B. Transcriptions in Elan were based on auditory impressions, and transcriptions in Praat were based on visual examination of waveforms and accompanying spectrograms in order to identify the acoustic characteristics and boundaries of segments using standard acoustic phonetic criteria (e.g. Ladefoged & Maddieson, 1996b). In some cases data were also explicitly transcribed at the segmental level, but the process here is separate to the closer, multi-tier segmentation and transcription undertaken in the experimental stage of the project, and discussed in 4.4.4.1, 5.4.4.1, and 6.4.4.1.

3.2.3.3 Lexical database

The aforementioned lexical database was created using Fieldworks Language Explorer (FLEx) (SIL International, 2016; Rogers, 2010), which allowed lexical data to be recorded in a relational database with a range of associated information. The fields used for each item include an orthographic form, broad phonetic transcription, gloss, longer definition, grammatical category, dialect area, and semantic domain. For some items, additional fields, for example for comments, a scientific name, or the source language of a borrowed word, were also used. Once constructed, the database also enabled searching across a number of parameters including the segmental and tonal content of a word, and its CV structure. Nouns have been entered in both singular and plural forms, given the largely unpredictable number-marking patterns, and verbs have mostly been entered in their primary infinitival forms, with some additional derived forms. The many and varied possibilities for inflected verb forms have not been entered in this database, but are recorded in associated transcribed materials. The database continues to be added to and updated in collaboration with Jonathan Moodie, whose ongoing work with members of the same community contributes additional data and analyses to the description of Lopit (Moodie, in progress).

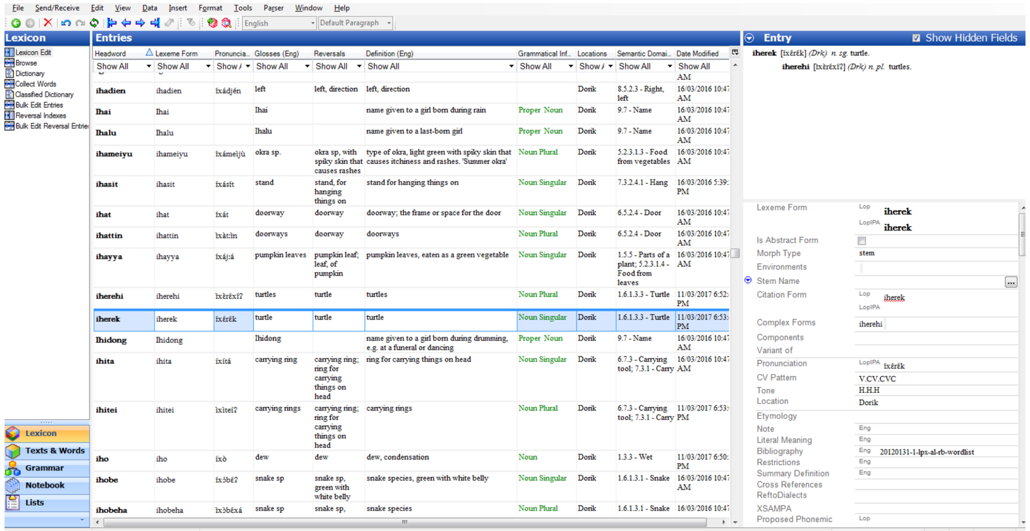


Figure 3.1: *Example of user interface for Fieldworks Language Explorer, which was used to construct the lexical database for the current project.*

3.3 Consonants

A Lopit consonant inventory is presented in Table 3.1, based on the data collection and analyses undertaken for the current project. Among the 27 consonants, Lopit has voiced and voiceless stops occurring at four supralaryngeal places of articulation, as well as a glottal stop which has a restricted distribution. As the overviews in 2.2.3 and 2.2.1 show, this is typical of most Eastern Nilotic languages - there is no evidence of a third, implosive stop series, as found in the Bari branch of Eastern Nilotic, nor is there evidence of a contrast between dental and alveolar stops, a characteristic of Western Nilotic consonant inventories. The glottal stop, which only occurs word-finally, is noted for a number of other Eastern Nilotic languages (and a word-initial glottal stop is found in some Western Nilotic languages), though as discussed, there is some uncertainty surrounding its status and origin in these languages. Other Lopit stops also exhibit limitations in their distribution; as shown in Table 3.2 and discussed in the relevant following sections, only three of the four voiced stops may occur word-finally, for the most part only in specific verbal inflections, and /k/ and /t/ are the only supralaryngeal voiceless stops to occur in final position. Syllable structure is discussed further in 3.6.

Nasal consonants are present at the same four supralaryngeal places of articulation as stops, which is also typical for Nilotic languages without a dental/alveolar distinction. There is no voicing contrast for fricatives, which occur at three main places of articulation, in addition to some marginal use of postalveolar [ʃ]. Only /f/ and /s/ may occur contrastively in final position. Though fricatives are uncommon in Western Nilotic languages, as noted in 2.2.2, alveolar /s/ is reliably found across Southern and Eastern Nilotic languages. Within Eastern Nilotic, fricative inventories vary, and tend to be larger for languages in the Lotuxo-Maa group. However, the status of fricatives in relation to voiceless stops at similar places of articulation is not always clear for individual languages. As will be noted throughout, there are indications of a possibly historical relationship between voiceless stops and fricatives in Lopit, though the exact nature of this is not yet clear.

Based on impressions of length, a singleton vs. geminate contrast is proposed for alveolar stops and for a number of sonorants, including the alveolar nasal and lateral. The contrast between the alveolar tap and a trill can be considered part of the same pattern.

The proposed length contrasts among sonorants also extend to palatal and labial-velar glides, and this is a finding of particular interest. As observed in 2.2.4, geminate glides are typologically unusual, and as discussed further in 5.2, they are thought to be marked due to the presumed challenge their high sonority poses to reliable perception (and perhaps production) of segmental boundaries. Despite their rarity, a similar contrast is proposed for all of the Lotuxo-Maa languages within Eastern Nilotic, and may also be used in a limited way in some Teso-Turkana languages. However, gemination is not evenly spread acoss Eastern Nilotic consonant types – for the Maa varieties, this appears to be the only productive contrast of this sort (also described as 'strong' compared to 'weak'), while in Lotuxo languages such as Otuho and Lopit, length contrasts have previously been proposed for at least the voiceless alveolar stop, the alveolar nasal and the alveolar lateral in addition to the glides. The phonemes proposed for Lopit are all discussed in more detail, with examples, in the following sections. Plosives and fricatives are treated together, because the relationship between these is of particular interest, and putative singletons and geminates for consonants of the same place and manner are also discussed together.

Table 3.1: *Lopit consonant inventory.*

	Labial	Lab D	Dental	Alveo.	Pal. Alv.	Palatal	Velar	Glottal
Plosive	p b			t d tː dː		c ɟ	k g	ʔ
Nasal	m			n nː		ɲ	ŋ	
Trill				r				
Tap/Flap				ɾ				
Fricative		f		s	(ʃ)		x	
Approx.	w wː					j jː		
Lat. Approx.				l lː				

Table 3.2: *Examples of obstruent contrasts in Lopit, by word position.*

C	Word-initial		Intervocalic		Word-final	
p	pàràn	stand in row INF [a]	ápʊ́tà	shout 1SG [b]	-	
b	bàtàk	pig SG [c]	xábàràk	cow owners PL [d]	aít:àb	bribe 1SG [e]
f	fàrá?	leaves PL [f]	tàfàrà	ponds PL [g]	ákáf	lift up 1SG [h]
t	tàfɛ̀ŋ	guinea fowl SG [i]	màtà	drink INF [j]	íxát	doorway SG [k]
tː	tːàmʊ̀ʔ	helmet SG [l]	mátːáʔ	farms PL [m]	-	
d	dàxà	eat INF [n]	sádá	stand wide INF [o]	aípàd	whip 1SG [p]
dː	-		sàdːâ	small seat SG [q]	-	
c	càrì	shin cover SG [r]	ácá	dance 1SG [s]	-	
ɟ	ɟátíʔ	vegetables SG [t]	xàɟàŋàʔ	flies PL [u]	áxɛ́j	fry 1SG [v]
s	sànáʔ	branches PL [w]	áságà	be tall 1SG [x]	áxás	hang 1SG [y]
k	kálìʔ	sides, edges PL [z]	wákàʔ	okra sp. PL [aa]	wárák	leopards PL [ab]
g	gàrì	animal track SG [ac]	mágál	hyena sp. SG [ad]	-	
x	xárí	river SG [ae]	wáxá	bushland SG [af]	-	
ʔ	-		-		xáláʔ	teeth PL [ag]

3.3.1 Plosives and fricatives

/p/

As noted, voicing is contrastive at the four supralaryngeal places of articulation, but the frequency of corresponding voiced and voiceless plosives is unbalanced. In Lopit, the voiceless bilabial plosive /p/ occurs very rarely. When it does occur, it typically occurs only word-initially and intervocalically, except for cases of reduplication, e.g. (1a) , and some instances in which /p/ forms a cluster with a labial-velar glide (1b).[1]

(1) a. pìk-pík motorcycle SG [ai] b. àpwânî second *fari* crop SG [aj]

/p/ is typically unaspirated, and is contrastive with the voiced bilabial plosive /b/ and the voiceless labiodental fricative /f/, for example in (2a), (2b), and (2c), and intervocalically in (2d), (2e), (2f). Additional examples of obstruent contrasts are listed in Table 3.2.

[1]It was noted (by a speaker of the Dorik dialect) that the Ngutira pronunciation for this would be /àfwání/.[ah]

There is no evidence that /p/ is contrastive in word-final position, but a voiceless bilabial stop can occasionally occur as a free variant of /f/, as discussed in later sections.

(2)
a. pɔ̂rɛ̀ʔ game type SG [ak]
b. bɔ̂rɛ̀ stable SG [al]
c. fótír warthog SG [am]
d. tɔ́pɔ̀t clean (with cloth) IMP [an]
e. tɔ́bɔ̀t go direct IMP [ao]
f. fɔ́fɔ́ŋ cactus trees PL [ap]

Vossen (1982, p. 190) observes that /p/ is replaced by [f] (or [ɸ]) intervocalically in Lopit, and transcribes most intervocalic voiceless labials accordingly, but in the present data there is good evidence that /p/ and /f/ contrast intervocalically, despite the low frequency for /p/. In the instances where /p/ does occur, it does not exhibit lenition to [f], but comparative data presented elsewhere (Driberg, 1932; Vossen, 1982) indicate that Lopit /f/ corresponds to /p/ in many other Eastern Nilotic languages and likely represents a change that took place some time ago for many Lopit words, which would also explain the relative infrequency of /p/. It is also worth noting that the status of /p/ is more tenuous among nouns, with most examples of /p/ occurring in borrowed and/or onomatopoeic words, but among verbs its presence is more robust. This is discussed further below.

Vossen (1982, p. 190) notes that medial geminate [pː] was found in a few Lopit words, but that evidence was too limited to propose it as phonemic. While this has not been noted by Turner (2001) or Stirtz (2014b), some similar examples appear in the present data, all in cases where /p/ is the first consonant of the verb root. A long closure is consistently produced in various inflections of the verb in (3a), which denotes the action of swinging something heavy, such as a gourd full of milk, back and forth on a rope. However, this has so far only been checked with one speaker. The verb in (3b) is also produced with a notably long closure for the voiceless bilabial stop, but this verb is not widely used. One speaker uses it at least sometimes (e.g. in a narrative), but in discussion, others note that they disprefer it, and it is suggested to be a possible borrowing from Otuho.[2] The verb in (3c) has been recorded with multiple speakers, and often, though not always, has a noticeably long closure, and the verb in (3d) is also occasionally produced with a per-

[2]Muratori (1948, p. 59) transcribes this word <ipːik>, and additionally records <ipːosjo> for 'swing' as a transitive verb Muratori (1948, p. 218).

ceptibly long closure. These examples are insufficient evidence that occurrences of [pː] are part of a length contrast among the labial stops, but more data are required to see if there is a pattern to duration differences.

(3)
a. xìpːɔ̀sà swing sth INF [aq]
b. aìpːíxɔ̀rì drag 1SG [ar]
c. xìpːàdà whip INF [as]
d. ápːɵ́rà bake 1SG [at]

/b/

The voiced bilabial plosive /b/ occurs frequently, but is very rare word-finally, a distributional pattern observed for voiced stops more generally. In the present study, no examples of word-final /b/ were found for any nouns, but /b/ can be a coda for words of other classes, for example in the adverbial in (4a), and in a number of inflected verbs, such as in (4b)-(4d). Stirtz (2014b, p. 24) did not find any examples of word-final /b/ in the five dialects studied apart from the example <hɔb> 'earth, ground' for the participant from the Dorik area (which differs from the pronunciation /xɔ̀f/[au] typically used by Dorik participants in the present study). However, this is likely because the particular verbal inflections in which word-final /b/ can appear (those which do not require a vowel after the final consonant in the stem) do not occur often, and were not among the nouns and imperative verb forms available for Stirtz's descriptive work. Vossen (1982, p. 190) did not find any examples of final /b/, likely also because of limitations in the available data, but Turner (2001, p. 27) found examples in similar contexts. Vossen (1982, p. 190) observed that /b/ was interchangeable with implosive [ɓ] "for no discernible reason". However, this does not appear to be the case in the data for the present study. Occasional prenasalisation is observed in emphatic speech. /b/ is generally fully voiced, but when word-final and pre-pausal, it is often unreleased, and is partially but not fully devoiced.

(4)
a. fàr túb all day [av]
b. ɔ́rɔ́b cut open, lance 3SG [aw]
c. ɛ̀sáb divide in half 3SG [ax]
d. tórùb sip.from.gourd IMP [ay]

/f/

The labiodental fricative /f/ occurs in all environments, though it is rare word-finally. It contrasts with other labial consonants /p/ and /b/, e.g. initially in (5a), (5b), and (5c). Medial contrasts are also found, e.g. in (5d), (5e), and (5f).

(5)
a. fúɾé name, song SG [az]
b. pùɾò dig dry ground INF [ba]
c. búɾíʔ open areas PL [bb]
d. xɔ́fɔ̀ɾɛ̀ palm leaf thatch PL [bc]
e. ɔ́pʊ́ɾà bake 3SG [bd]
f. ɔ́bɔ́ɾɔ́ be large 3SG [be]

Intervocalically it may become partly voiced and approach [v], but this is most apparent in instances where /f/ is followed by a glide. For example, /xìfjôŋ/ 'water' is frequently produced [xìvjôŋ][bf]. It is not uncommon for /f/ to be realised as a voiceless bilabial fricative [ɸ] for some speakers, and voiced [β] may also appear. This possible variant was also observed by Vossen (1982, p. 190) and Turner (2001, p. 10) for Lopit, as well as Coates (1985, p. 90) for Otuho, and is most frequent when /f/ occurs intervocalically.[3]

It is clear from comparative data presented by Vossen (1982) that /f/ in Lopit corresponds to /p/ in many other Eastern Nilotic languages, particularly intervocalically, and that seemingly a change from /p/ to /f/ has taken place in a number of words, but what is interesting to note is the instances in which this has not occurred. While there are some nouns with /p/ in medial position, most of the examples of medial /p/ are inflected verb forms in which /p/ is the first consonant of the stem. For example, the noun in (6a) is derived from the verb in (5b) via a regular process, and although the stem-initial consonant of the verb is /p/, the derived noun is almost always produced with [f].[4] However, when /p/ occurs in a phonotactically similar environment to the labial in (6a), but in an inflected verb form, as in (6b), /p/ is consistently retained.

(6)
a. ífúɾʊ́t digging tool SG [bi]
b. ípúɾò dig dry ground 2SG [bj]

It may be that for verbs, this is a particularly salient position in which /p/ is more resistant to change, though /f/ is also attested as the first consonant of a verb stem, e.g. in (7a) and (7b), compared to the earlier example with /p/ (sometimes [pː]) in (3c).

[3] It is worth noting that the results of ritual tooth extraction, a widespread practice among Nilotic groups, mean that some speakers do not have the option of producing any labiodental consonants. While it is typically lower incisors or canines that are removed in this practice, upper incisors are known to sometimes come out at a later time, and this was the case for one of the women contributing to this study. The extraction is usually performed in early adolescence, but is reportedly less popular today. See Edmondson, Silva and Willis (2008) for a discussion of some of the consequences for articulation, with reference to dental restoration procedures sought by speakers of Dinka in the United States.

[4] Both [ípúɾʊ̌t][bg] and [ípúɾít][bh] have, however, been suggested during discussions where the noun was considered in relation to the source verb.

(7) a. xíffítà tie INF [bk] b. xìfúfúsòʔ rub INF [bl]

There are only two word-final examples of /f/ among nouns, (8a), as noted earlier, and (8b). Occasionally, a final [p] has been heard for /xɔ̀f/, but only for some speakers,[5] and only pre-pausally in natural speech. When this occurs, the [p] is unreleased, and while impressions are that it is unvoiced, it may be similar to word-final realisations of /b/. In Vossen (1982, p. 190), the Lopit word for 'tongue' is given as <ŋáɟɛ́p>,[bm] but in Stirtz (2014b, p. 45) it is reported as <ŋádjɛ́f> [bn] for the five Lopit dialects studied (tones only apply to Ngutira data), and in Stirtz (2014b, p. 34), the word for 'earth, ground' is given as <hɔb> [bo] for the Dorik dialect, but different forms are recorded for the other four dialects studied.[6]

(8) a. xɔ̀f earth, ground SG [bp] b. ŋádjéf tongue SG [bq]

The labiodental fricative can also be found as a coda in inflected forms of several verbs, for example (9a) - (9d), in a similar pattern as observed for /b/. No word-final examples of /f/ in verbs have been noted with [p] realisations.

(9) a. aíŋɔ̀f hide sth 1SG [br] b. aíŋèf trap 1SG [bs]
c. ákɔ́f catch 1SG [bt] d. ákáf lift up 1SG [bu]

/t/

The voiceless alveolar plosive /t/ is a very frequently occurring consonant in Lopit, and can occur in all word positions for all word classes. It clearly contrasts with the voiced alveolar plosive /d/, for example initially in (10a) compared to (10b), and medially in (10c) compared to (10d). In initial and medial positions, auditory impressions are that /t/ is generally produced with no substantial aspiration, and visual inspection of spectrograms confirms the tendency towards very short voice onset times (see e.g. Figure 3.2a, and later examples Figure 4.1a and Figure 4.1b). Word-finally, /t/ is often unreleased, but it can sometimes be realised with an audible period of aspiration in this position with

[5] One of the speakers for whom these examples are noted is the aforementioned participant who lacks upper and lower central incisors.

[6] This may have arisen through metathesis either in the Dorik dialect, or in all the other dialects; in Stirtz (2014b, p. 34), the word is given as <fɔ̀k> for Ngutira, <fɔw> for Lomiaha, <faw> for Lohutok and Lolongo.

emphatic productions. Examples of word-final contrasts can be found with discussion of /d/, below.

(10)

a.	táfár	pond SG [bv]	b.	dàxà	eat INF [bw]
c.	fɛ̀tɛ̀k	fishing spear SG [bx]	d.	fɛ́dɛ́	calabash, dish SG [by]

Stirtz (2014b, p. 20) observes that in the Ngutira dialect of Lopit, /t/ is realised as voiceless palatal plosive [c] when it precedes /j/ at morpheme boundaries and elsewhere, e.g. (11a) compared to (11b), but specifically notes that in the Dorik dialect, [t] remains in these contexts. This is supported by my own Dorik data, e.g. (11c) compared to (11d), and other examples such as (11e) in the present study, which is reported to be (11f) in the other four dialects studied by Stirtz (2014b, p. 35). Visual inspection of spectrograms shows that while there is some affrication of /t/ in these contexts, it has a consistently alveolar closure for the Dorik speakers participating in this study. Furthermore, this dialectal difference appears to be salient to the speakers, and in instances where two speakers demonstrated the Ngutira variant, the closure is clearly postalveolar and the period of frication longer.

(11)

a.	<mɔ̀tì>	pot SG [Ngutira - TS] [bz]	b.	<mɔ̀cjɔ̂>	pots SG [Ngutira - TS] [ca]
c.	mòtì	pot SG [cb]	d.	mòtjô	pots PL [cc]
e.	tjàŋ	animal (general term) SG [cd]	f.	<cjàŋ>	animal SG [Ngutira - TS] [ce]

In the present data, there is a clear contrast between /t/ and the alveolar fricative /s/ as well as palatal plosive /c/, as in (12a) compared to (12b) and (12c).

(12)

a.	tùxê	raven sp. SG [cf]	b.	sʊ́xɛ́	chest SG [cg]
c.	cùxò	stab INF [ch]			

/tː/

In addition to the voiceless alveolar plosive /t/, there is a geminate voiceless alveolar plosive /tː/, also typically unaspirated (see e.g. Figure 3.2b). Of the geminate consonants in Lopit, this geminate alveolar occurs the most often, though all geminates are less common than their singleton counterparts. The geminate /tː/ clearly contrasts with /t/ in medial positions, for example in (13a), (13c), and (13e) compared to (13b), (13d) and (13f).

(13)
a. át:ɛ́là pull 1SG [ci] b. átɛ́là watch 1SG [cj]
c. xìt:ò bottom SG [ck] d. xìtó child SG [cl]
e. mát:áʔ farms PL [cm] f. màtà drink INF [cn]

/t:/ also contrasts with /t/ word-initially, for example in (14a) compared to (14b).

(14) a. t:ɔ̀xɔ̀ kill, hit INF [co] b. tɔ́bɔ́k clay bowl SG [cp]

Most word-initial examples are infinitive verb forms or verbal nouns, such as (15a) and (15b), which can occur alone in particular constructions. The geminate alveolars remain when person-marking prefixes are added to the verb stems, for example as in (15c) and (15d).

(15)
a. t:oí dryness [cq] b. t:ùxò be deaf INF [cr]
c. ót:oí be dry 3SG [cs] d. ót:úxò be deaf 3SG [ct]

Similarly, geminate consonants are preserved across different inflected forms of nouns, as in (16a) to (16d), providing good evidence that their occurrence is not generally a result of prosodic or morphophonological context.

(16)
a. xàt:ɛ̀l eggs PL [cu] b. xàt:élí egg SG [cv]
c. xát:ɛ̀l eggs PL NOM [cw] d. xát:èlì egg SG NOM [cx]

However, for some examples occurring at morpheme boundaries in number-marked forms, there are indications that a morphophonological process may have applied at some stage. For example, for the nouns in (17a) and (17b), with an alveolar tap and stop respectively as the final consonant in the word, the plural forms, shown in (17c) and (17d), appear to involve /t:/ instead. Gemination here could therefore derive from affixation of the plural suffix /-(C)ɪn/ (the initial consonant of this suffix varies between /ɟ/, /s/ and [ʃ]).

(17)
a. bɔ̂rɛ̀ stable SG [cy] b. íxát doorway SG [cz]
c. bɔ̀t:ìn stables PL [da] d. ìxàt:ìn doorways PL [db]

For the monomorphemic plural 'hair, feathers', shown in (18a), there is a marked singular[7] with a geminate, as in (18b), as well as an option which instead retains a rhotic,

[7]See 1.4.3 Moodie (2016) for more details on tripartite number-marking in Lopit.

as in (18c). While some speakers express a preference for one over the other, and suggest possible dialect differences, or that perhaps one singular form is more common for the 'hair' sense, and the other for the 'feathers' sense, both appear to be freely used by all the Dorik participants, in both senses.

(18)
a. xòfìr hair, feathers PL [dc]
b. xòfîtːî hair, feather SG [dd]
c. xófíɾí hair, feather SG [de]

There are only a small number of examples of this possible morphophonological gemination, and it is not a productive pattern, as shown in (19). Examples (19a)–(19b) exhibit the same pattern as in (17), but examples (19c)–(19d) do not.[8] However, examples such as these suggest the possibility that sequences of coronal consonants (such as an alveolar followed by an alveolar or postalveolar), perhaps arising after vowel deletion, may have led to some of these instances of geminate /tː/. This is discussed further below in relation to geminate alveolar nasals.

(19)
a. mʊ́rʊ́t neck SG [df]
b. mùtːò necks PL [dg]
c. xìmʊ̀rʊ̀t mosquitoes PL [dh]
d. xìmúrùtî mosquito SG [di]

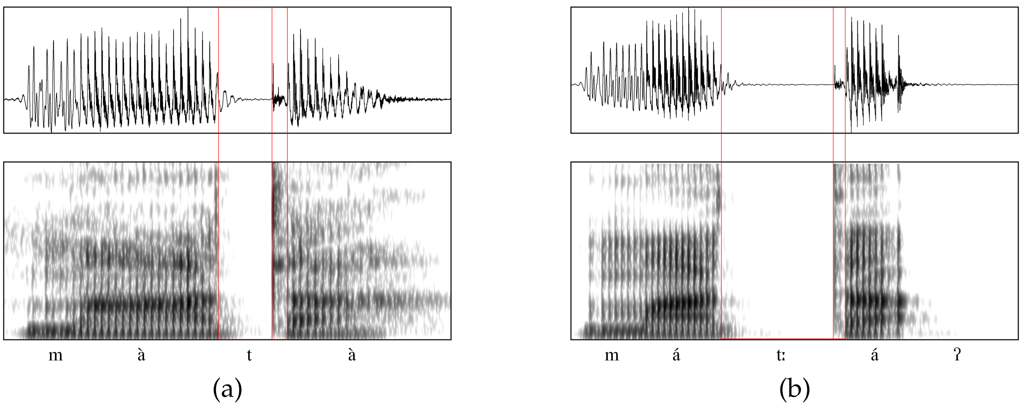


Figure 3.2: *Acoustic waveform and spectrogram of voiceless alveolar stops in /màtà/ 'drink* INF*' and /mátːáʔ/ 'farms* PL*' (dynamic range 50dB, duration 600ms).*

Impressionistically, the major cue to the difference between geminate /tː/ and singleton /t/ is closure duration, which as noted in 2.2.4 is the most consistent phonetic correlate of

[8] However, one Dorik participant suggested that /xìmútːì/ might be used in the Ngutira dialect.

length contrasts crosslinguistically. Lopit participants in this study characterise the difference as between 'heavy' and 'light' sounds (as did those consulted by Turner (2001)). Where spectrograms of /tː/ tokens have been checked, differences in closure duration are apparent, e.g. as seen in Figure 3.2. However, there are likely to be some additional differences in the articulation of these consonants; while /t/ is clearly apical, and appears to have articulations ranging from dental to alveolar, /tː/ may be produced with a slightly more laminal articulation, and while it tends to be alveolar, occasional tokens ranging from dental to slightly postalveolar have been perceived. Turner, who similarly proposes a contrast between 'strong' and 'weak' voiceless alveolar plosives, likewise notes that the latter tend to be apical and have a shorter closure, while the former have a longer closure, and potentially greater contact between the tongue and alveolar ridge (Turner, 2001, p. 9). Turner also finds evidence for this contrast word-initially (Turner, 2001, p. 12). Though Stirtz (2014b, p. 10) writes that "there is some evidence for contrastive consonant length in roots", only word-medial and no word-initial examples were transcribed in the data at hand, and therefore long consonants were analysed as sequences of two identical consonants in adjacent syllables.[9]

/d/

The voiced alveolar plosive is much less frequent than its voiceless counterpart /t/, but still widely found in initial and medial positions, as shown earlier. However, there are no word-final examples in the current data apart from inflected forms of two verbs, 'bend', as in the infinitival (20b) compared to (20a), and 'whip, kill', as in (20d) compared to (20c). The latter may be cognate with a verb for which Turner (2001, p. 26) found word-final /d/, reported as <fád>'defeated/destroyed', though none of the Dorik speakers this was checked with knew of a word with this form. /d/ is unreleased word-finally, as for /b/, and this restricted occurrence of /d/ is similar to the situation noted for /b/. It is possible that other examples of word-final /d/ will emerge as more verbs with /d/, and of

[9] This analysis is likely partially for practical reasons, influenced by the orthographic goals of the study; Stirtz explicitly notes regarding the alternative, separate long consonants, that "[s]uch an analysis adds at least the six consonant phonemes /tː/, /dː/, /lː/, /rː/,/wː/, /yː/ and is therefore not taken in this description" (2014, p. 11).

the appropriate verb class, emerge and can be tested in these inflections. Neither Vossen (1982, p. 190) nor Stirtz (2014b, p. 9) found any examples of word-final /d/.

(20)
a. kùdò bend INF [dj] b. tókùd bend IMP [dk]
c. xìpàdà whip INF [dl] d. ɛípàd whip 3SG [dm]

There is clear contrast between /d/ and the alveolar tap /ɾ/, for example in (21a) compared to (21b).

(21) a. mɛ́djɛ́ʔ spinach sp. SG [dn] b. méɾjéʔ red ochre [do]

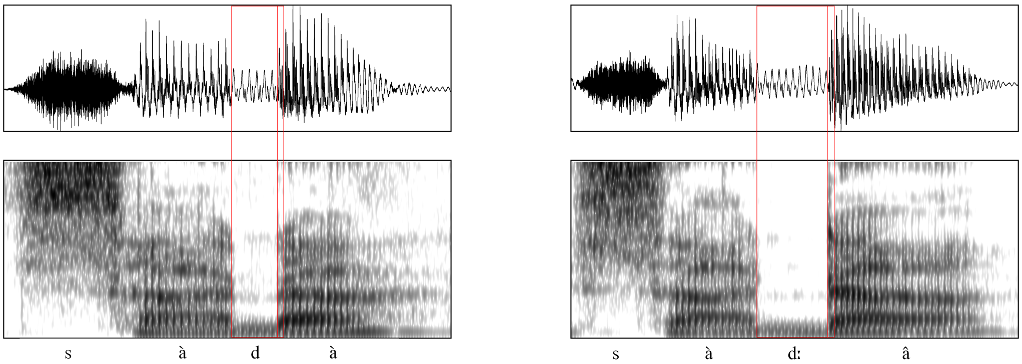
/d/ has an implosive variant [ɗ] which is optionally produced in some words. It has only been recorded word-initially and preceding non-front vowels, and is most apparent for words produced in isolation. Examples include [ɗómí] 'knife SG'[dp], [ɗɔ́ŋɛ́] 'mountain SG'[dq], [ɗóŋíʔ] 'drums PL'[dr], and [ɗàxà] 'eat INF'[ds]. All of these words may also be produced without the implosive, particularly the latter example. Vossen (1982, p. 190) previously noted that there appeared to be free variation between /d/ and [ɗ]; it may be that this is now limited to a particular environment and particular lexical items. Alternatively, it could be a word-initial realisation of geminate /dː/, which is otherwise not attested in this position, a possibility discussed further below.

/dː/

There is a geminate alveolar plosive /dː/ which occurs very rarely, but does contrast with /d/ word-medially in a small number of examples, for example in (22a) compared to (22b), and (22c) compared to (22d) (see Figure 3.3).

(22)
a. xàdːétí root SG [dt] b. àdèrî red sorghum sp. PL [du]
c. sàdːâ small seat SG [dv] d. sàdà stand wide INF [dw]

Though the examples are few, these pronunciations are consistent across speakers, and the consonant length is preserved across both singular and plural forms of the nouns, for example in (23a) compared to (22a), and in (23b) compared to (22c). Vossen (1982, p. 189) does not note a geminate voiced alveolar at all, but Stirtz (2014b, p. 37) found tokens of it in the words for 'root' and 'roots', as also seen in (22a) and (23a) in the current



(a) (b)

Figure 3.3: *Acoustic waveform and spectrogram of voiced alveolar stops in /sàdà/ 'stand with wide stance* INF*' and /sàdːâ/ 'small seat* SG*' (dynamic range 50dB, duration 600ms).*

project, and this medial presence of /dː/ appears to be consistent across the five dialects studied in that work.

(23) a. xàdːɛ̀ʔ roots PL [dx] b. sàdːâxîn small seats PL [dy]

There are no word-final examples of /dː/, and, in my own data, no word-initial examples. However, Turner (2001, p. 12) does find at least two word-initial examples of what he terms the 'strong' voiced alveolar consonant, a label which, as discussed in 2.2.4 refers to impressions of longer closure, as well as possible differences in articulation and the degree of voicing. One of these examples is in the word for 'drums', which in the present data is often realised as a somewhat imploded stop, as discussed above. This raises the question of whether the initial imploded tokens in my data are realisations of /dː/, but it is worth noting that these tokens do not have a closure that appears to be any longer than for tokens of /d/, which differ from impressions for /tː/ above (whereby initial /tː/ does have a long closure phase). In addition, Turner (2001, p. 12) suggests that the initial voiced alveolar consonant of 'drums' contrasts with that of 'mountain' on the basis of the strong/weak distinction, but as shown earlier, this is another word which often has an imploded initial stop in the present data.

In the current data, when words such as these are produced in inflected forms which cause the stem-initial stop to be intervocalic rather than word-initial, the realisation does not show signs of implosion, nor of length differences, as shown in (24a) and (24b) compared to the earlier examples [ɗóɲíʔ] 'drums PL' and [ɗàxà] 'eat INF'. This is unlike the situation for /tː/, for which it has been shown that proposed length differences are maintained across inflections. Given this, at this stage it seems that in the current data, /dː/ does not contrast word-initially, and that /d/ has a free variant [ɗ] which is a word-initial option.

(24) a. xìdòŋ drum SG [dz] b. ádáxà eat 1SG [ea]

/c/

The voiceless palatal plosive /c/ has a laminal articulation, involving contact between the tongue blade and the passive articulator. As for many languages described as having laminal palatal consonants, the place of articulation is likely more anterior than the term 'palatal' suggests, and may be more accurately described as alveo-palatal, though further work will be required to precisely identify the nature of the articulation. Turner (2001, p. 10) proposes a voiceless postalveolar affricate /tʃ/ rather than a voiceless palatal stop. In the present data, /c/ may be realised with some affrication, as is common for laminal articulations, but the degree of this is variable; it is more apparent in initial position, and in emphatic productions, and more noticeable among some speakers than others. /c/ occurs in a range of environments but is not found word-finally. It contrasts with other palatal consonants in initial positions, for example in (25a) compared to the voiced palatal plosive in (25b), and medially as in (25c) compared to (25d).

(25) a. cɔ̀lâ men's sticks PL [eb] b. ɟʊ̀là push INF [ec]
c. ácúk stab 1SG [ed] d. xàɟʊ́r white pumpkin sp. [ee]

The voiceless palatal plosive also contrasts with the voiceless alveolar fricative /s/, for example initially in (26a) compared to (26b), and medially in (26c) compared to (26d). This differs from findings reported by Stirtz (2014b), who did not observe /s/ produced by the Dorik participant in his study in any words; instances of /s/ in other dialects corresponded to /c/ for the Dorik speaker. Possible reasons for this difference are discussed in more detail below.

(26) a. cɔ́bɔ̀ spinach sp. PL [ef] b. sɔ̀lɔ́ʔ spoon, shell SG [eg]
c. ɛ̀cà dance 3SG [eh] d. ɛ̀sáʔ rain 3SG [ei]

In addition, Stirtz (2014b, p. 36-37) lists some examples of word-final /c/ in a small number of Dorik Lopit words (also corresponding to /s/ in other dialects), such as (27a) and (27b).

(27) a. <hac> hands PL [Dorik - TS] [ej] b. <ɡuc> skin SG [Dorik - TS] [ek]

This suggests that for at least some Lopit speakers, the voiceless palatal plosive can occur word-finally. In contrast, the Dorik participants in this study consistently produced word-final /s/ in these words and many others, for example as in (28a) and (28b), and in other examples as shown elsewhere, e.g. in (31). For this group, /c/ does not appear to be contrastive word-finally.

(28) a. xàs hands PL [el] b. ɡʊ̀s pelt SG [em]

However, for one participant, in a small number of words, some variation between final /s/ and /c/ has been noted; for example, the nouns in (29) were alternately produced with both, with /c/ perhaps more likely when the pronunciation was under careful consideration. When checked with other speakers, the /c/-final realisations were dispreferred.

(29) a. lɔ́bɔ́c pot type SG [en] b. lɔ́bɔ́s pot type SG [eo]
c. lɔ́xʊ̀ɾɛ̀c bird sp. SG [ep] d. lɔ́xʊ̀ɾɛ̀s bird sp. SG [eq]

/ɟ/

There is a voiced palatal plosive /ɟ/, which contrasts with the voiceless palatal plosive, as discussed above, and is also laminal in articulation. It also contrasts with the palatal approximant, for example initially in (30a) compared to (30b), and medially in (30c) compared to (30d).

(30) a. ɟànî broom SG [er] b. jànì tree SG [es]
c. áɟétò sleep 1SG [et] d. ájɛ́fà lash, chop 1SG [eu]

As for the voiced plosives /b/ and /d/, /ɟ/ can occur word-finally but there are only a small number of examples, all of them in particular verbal inflections, for example as in (31a). Though /c/ is not contrastive word-finally, (31b) shows that final /ɟ/ contrasts with /s/, which as noted shows some evidence of a relationship with /c/. In final position, there is a small amount of devoicing but /ɟ/ typically remains more voiced than not. Turner (2001) describes this consonant as an affricate /dʒ/, but notes that word-finally it is unreleased and more like [dʲ], likely reflecting the typically unreleased nature of Lopit plosives word-finally. He similarly describes it as "slightly devoiced" in this position (2001, p. 10).

(31) a. áxɔ́ɟ scratch 1SG [ev] b. xɔ̀rɔ̀s debt SG [ew]

/s/

The voiceless alveolar fricative /s/ is commonly found in Lopit, though its use likely varies among the different dialects. For the Dorik participants in this study, there are many consistent examples of contrast between /s/ and /c/, but as noted, the same was not found for the Dorik participant who contributed to descriptive work by Stirtz (2014b); this speaker used only /c/. Initial and medial examples from the present study include (32a) compared to (32b), and (32c) compared to (32d), as well as those shown earlier in (26).

(32) a. sálì fireplace SG [ex] b. càrì shin cover SG [ey]
c. tɛ́sàb divide IMP [ez] d. tɛ́cà dance IMP [fa]

However, there are some interesting patterns in the distribution of these segments. As noted above, /s/ can occur word-finally, while /c/ for the most part cannot, but both may occur in initial and medial positions. But, in intervocalic contexts, /c/ is rare except in cases in which it is the initial consonant of a verb stem. As in (32c)–(32d), both /c/ and /s/ occur in verb stems, allowing them to occur with various preceding vowels used for inflection, but among nouns, /s/ is much more frequent than /c/ intervocalically. Examples of contrast between /s/ and /c/ in nouns can, however, be found, as in (33a) compared to (33b) and (33c) compared to (33d).

(33) a. ísɔ̀gìʔ millipede SG [fb] b. ìcó honey SG [fc]
c. mìsítì spinach sp. IMP [fd] d. cícílá incisors PL [fe]

Given the evidence of dialectal variation presented by Stirtz (2014b), and the discussion below regarding the possibly intermediate role of ([ʃ]), it seems that while /s/ was likely already present in Lopit, there may be, or have been, a process of lenition operating differently across the dialects, and which is resisted by /c/ when it is the initial segment of a verb stem.

[ʃ]

Occasionally, [ʃ] is produced by some speakers, for some words. While its status is not entirely clear, examples available at this stage suggest that it is a free variant of /s/. In some cases, individual speakers have a clear preference for a production with [ʃ] over [s] in a particular word. For example, in the proper noun shown in (34), several speakers consistently produce the intervocalic fricative as [ʃ], as in (34a), and furthermore note this as the canonical pronunciation, while others alternate between this and the form with [s], shown in (34b). The other noun shown is consistently produced with final [ʃ] by at least one speaker, as in (34c), while others reliably use [s], as in (34d).

(34)
a. lɔ̀ʃàrʊ̀k Losharuk village [ff]
b. lɔ̀sàrʊ̀k Losharuk village [fg]
c. dùʃ grass sp. [fh]
d. dùs grass sp. [fi]

In some other cases all speakers may freely use either [ʃ] or [s]; this can be seen, for example, in (35a) and (35b) (for which the diphthong quality also varies), and the variation is likely influenced by the presence of /ʃ/ in the Arabic source word for this borrowing. The fricative variation is particularly apparent when instances of the plural-marking suffix /-Cɪn/ are considered; while the forms with both [ʃ] and [s] appear to be variants of the same suffix, some speakers appear to sometimes prefer one over another in certain words, while freely alternating between the two for others. Some examples are shown in (35c) to (35f). The presence of this variation before the same close vowel suggests it is not an effect of vowel quality.

(35)
a. ʃaî tea [Arabic] [fj]
b. seî tea [Arabic] [fk]
c. lòlûʃɪ̂n head-dresses PL [fl]
d. ɪ̀ŋɛ̂sɪ̂n babies PL [fm]
e. xɪ̀làʃɪ̂n thunderstorms PL [fn]
f. ɪ̀tíxòsɪ̂n zebras PL [fo]

There is one instance in which [ʃ] appears to vary with [c], as well as [s], with the possibility of a following palatal glide as a further option; for the singular and plural forms of the noun shown in (36), four possible forms have been noted, and speakers are quite consistent in (and have strong preferences about) which of these forms they use.

(36)	a. lɔ̀cɛ̂r corn PL [fp]	b. lòcêrî corn SG [fq]
	c. lɔ̀ʃjɛ̂r corn PL [fr]	d. lòʃjèrî corn SG [fs]
	e. lɔ̀sjɛ̂r corn PL [ft]	f. lòsjêrî corn SG [fu]
	g. lɔ́sɛ́r corn PL [fv]	h. lòsérì corn SG [fw]

As noted above, Stirtz (2014b) did not find evidence of a contrast between /c/ and /s/ for the Dorik participant in his study, who used only /c/ (while the speakers of the other dialects had both), but there is clear and consistent evidence for such a contrast among the Dorik participants in this study. However, it is possible that these marginal uses of [ʃ] capture the remains of some change from /c/ to /s/ in a number of words. Further work across Lopit speakers and dialects will be required in order to understand any patterns, and it is worth recalling that as noted in 2.2.2 the status of coronal (and other) fricatives is the subject of some uncertainty, and a great deal of variation, in a number of Eastern Nilotic languages.

/k/

The voiceless velar plosive /k/ occurs often in Lopit, and can be found in all positions. It contrasts with the voiced velar plosive /g/ and the voiceless velar fricative /x/, as can be seen in (37a) compared to (37b) and (37c), and medially in (37d) compared to (37e) and (37f). It often occurs word-finally, and is the most common word-final obstruent apart from the glottal stop, partly because it occurs in several suffixes as well as on morphologically unmarked words. As for /t/, /k/ is typically unaspirated in initial and medial positions, and is generally unreleased word-finally, though also as for /t/, word-final articulations may sometimes be accompanied by aspiration (see e.g. Figure 3.7a).

(37)	a. kùrèk small hoe SG [fx]	b. gúló be bent INF [fy]
	c. xùrêʔ some F [fz]	d. tɔ́kɔ̀l hollow out IMP [ga]
	e. tɔ́gɔ́lɔ̀ be strong IMP [gb]	f. tːɔ̀xɔ̀ kill INF [gc]

/k/ is attested in previous work by Vossen (1982); Turner (2001) and Stirtz (2014b), but Vossen (1982, p. 191) is more tentative about whether it contrasts with /x/; he states that in Lopit, /k/ tends to change into [x] (and sometimes [h]) intervocalically except when preceded by /i, ɪ/ and followed by /a/. He gives the example /íkát/ 'door', which, as can be seen in Table 3.2, has /x/ rather than /k/ in the current data. In the present study, there are various examples showing that the two do contrast in this context, as in (38a) compared to (38b), and many others, for example in (38c)[10] compared to (38d).

(38)
a. íkáfútì bat sp. SG [gd] b. íxámeìjù okra sp. PL [ge]
c. ìkúdòʔ squirrel, story SG [gf] d. ìxùlóʔ calabash SG [gg]

However, there is clearly a relationship between /k/ and /x/, similar to that between /p/ and /f/, as discussed above; a number of words with /x/ in the current study are transcribed with /k/ in early wordlist data collected by Driberg (1932), and correspond to words with /k/ in Eastern Nilotic languages outside the immediate Lotuxo family (Vossen, 1982). However, languages closely related to Lopit appear to share the contrast, at least in the case of Otuho (Coates, 1985). In specific morphological contexts, a lenition process leading to a realisation of intervocalic /k/ as [x] can be proposed; for example, for Class 1 verbs with a CVC stem, the stem-final consonant can be word-final in some inflections, but is followed by a -V suffix in others, and where the stem-final consonant is /k/, as in (39a) and (39c), the intervocalic realisation at the morpheme boundary is [x], as in (39b) and (39d).

(39)
a. ábák hit 1SG [gh] b. ábáxà hit 1SG IPFV [gi]
c. èrjók be dark 3SG [gj] d. èrjóxó be dark 3SG IPFV [gk]

A similar pattern is observed when number-marking suffixes involving /o, ɔ/, /a/, or /i, ɪ/ are added to nouns ending in /k/, for example in (40a) compared to (40b), (40c) compared to (40d), and (40e) compared to (40f).

(40)
a. íbeìjùk owl SG [gl] b. ìbeìjúxíʔ owls PL [gm]
c. kùrèk small hoe SG [gn] d. kùréxɔ́ʔ small hoes PL [go]
e. bàtàk pig SG [gp] f. bàtàxâ pigs PL [gq]

A similar process has also been observed by Turner (2001, p. 26) and Stirtz (2014b, p. 18), and in the present data, it is also applied to borrowed words, for example as

[10]The word for 'squirrel' is also used as a general word for 'story', because of a popular genre of Lopit children's stories featuring a wily squirrel.

in (41), suggesting it is productive. While lenition of stops to fricatives is a common phonetic process among the world's languages, it is not common for this to result in the neutralisation of a contrast between phonemes (Gurevich, 2004), as for /k/ and /x/ in this case. Other voiceless stops in Lopit do not show regular alternations of this sort with fricatives.

(41)	a. sènúk box SG [Arabic] [gr]	b. sènúxíʔ boxes PL [gs]
	c. bʊ́k book SG [English] [gt]	d. búxìʔ books PL [gu]

However, the situation is likely more complicated, as sequences of /x/ followed by /o, ɔ/, /a/, or /i, ɪ/ in number-marked nouns also occur in numerous instances where /k/ is not present as a stem-final consonant. Very often, the stem-final consonant is /ʔ/, as in (42a) compared to (42b), and (42c) compared to (42d), and sometimes, the unmarked form has an open final syllable, as in (42e) compared to (42f).

(42)	a. lɔ́sàjːèʔ messenger SG [gv]	b. lɔ̀sàjːéxíʔ messengers PL [gw]
	c. xádórɪ́ʔ tortoise SG [gx]	d. xàdòrɪ́xòʔ tortoises PL [gy]
	e. ílátá oil SG [gz]	f. ìlàtáxá bowls of oil PL [ha]

This could mean that /ʔ/ should be interpreted as also having a variant [x], and raises questions about whether this relates in any way to the origins of /ʔ/; perhaps historically, /k/ had an allophone [ʔ] in some word-final contexts. However, examples such as (42f) suggest that /x/ may also have been generalised as an element of number-marking suffixes. In work on number-marking patterns in Lopit, which as noted in 1.4.3 involve a large number of possible morphemes, and are largely unpredictable, there are indications that the CV structure of a word has some influence on the choice of affix. Several suffixes, including these, are proposed to have both V and CV allomorphs which are chosen based on the syllable structure of the stem (Moodie, 2016).

/g/

The voiced velar plosive /g/ is much less common than the voiceless velar obstruents /k/ and /x/. It contrasts with other velar consonants, as noted above, and occurs both initially and medially. No word-final examples have been observed. This may seem to be a gap in the distribution pattern of segments, given that voiced plosives /b/ and /d/

do occur word-finally. However, it should be recalled that apart from some adverbial expressions, /b/ and /d/ only occur word-finally in specific inflections of verbs containing these segments as the last consonant in the stem, and a comparable instance of /g/ in the relevant environment has not yet been found. /g/ is the least common of the three voiced plosives, but it is possible that further verbal data will reveal some word-final examples. /g/ is also noted as contrastive by Vossen (1982), Turner (2001) and Stirtz (2014b), and similarly, none find any word-final examples. Interestingly, Vossen (1982, p. 191) notes that he found no examples of /g/ at all in data for the closely-related Dongotono language.

The voiced velar stop does not show any lenition patterns of the sort observed for the voiceless velar stop, and only one notable example of variation has been observed so far. For the words 'chest SG' and 'chests PL', the production used by most participants has /g/, as in (43a) and (43b), but two participants prefer forms with /x/, as in (43c) and (43d). This is likely a preference influenced by dialectal differences across Lopit, rather than evidence of intervocalic lenition, as the participants are consistent in the use of their respective preferences and the variation is so far only evident in this word. Stirtz (2014b, p. 25) notes specifically for this word that the Dorik participant in his study uses /g/ while the participants from more southern dialect areas use a fricative.

(43)
a. sʊ́gɛ́ chest SG [hb]
b. sʊ̀gɛ̀nàʔ chests PL [hc]
c. sʊ́xɛ́ chest SG [hd]
d. sʊ̀xɛ̀nàʔ chests PL [he]

/x/

The voiceless velar fricative /x/ occurs very frequently in Lopit. It is found word-initially and word-medially, and clearly contrasts with other velar consonants in these positions, as discussed above and as shown in Table 3.2. It is not found word-finally. As shown in (39), word-final /k/ is produced where /x/ might have occurred, if it were the phonemic consonant of the stem, and instead it seems that a process of lenition from /k/ to [x] operates in specific intervocalic and morphological contexts. /x/ differs, then, from fricatives /f/ and /s/, both of which are permitted word-finally, including in inflections of the sort shown in (39).

Both Vossen (1982) and Turner (2001) similarly propose a voiceless velar fricative in

Lopit, though Vossen is less certain of its status in relation to /k/, as noted above. Stirtz (2014b, p. 25) proposes glottal fricative /h/ as the phoneme, with different realisations depending on the speaker, word and utterance speed, and also influenced by the vowel environment, with [x] more likely preceding /a, ɔ/, [ɣ] preceding /ɔ, u/, and [h] preceding /i, ɛ/. While the analysis based on the data in the present study is slightly different, some variation of this sort is also observed. Auditory impressions suggest the place of articulation is often quite retracted, though not quite uvular, particularly preceding non-front vowels, while [ç] can be heard preceding close front vowels. However, the degree of constriction also varies; impressionistically, /x/ has only a very subtle velar gesture at times, particularly when it occurs word-initially and particularly when, in initial position, it precedes close front vowels /i, ɪ/, as well as in very rapid speech. The auditory cues to the segment can approach [ɰ̥], [h] and [ɦ] in these cases. While some voicing of the fricative can occur intervocalically, fully voiced [ɣ] has rarely been perceived in the present data.

Despite this variation, and the possibility of glottal articulations, the velar nature of the articulation does seem salient to speakers; for example, in some instances where I have used a glottal fricative in an attempt to reproduce a given word, I have specifically been told "You need to vibrate your tongue more". Furthermore, evidence of the 'velar pinch' (as the second and third formants approach each other in transitions to the consonant) can sometimes be seen in spectrogram examples, and a dorsal gesture was observed during mid-sagittal ultrasound tongue imaging for the vowel analyses in 4.7 (for words which included /x/ tokens). This suggests that speakers do draw on a supralaryngeal articulatory target, but that the place and degree of constriction is subject to a great deal of variation. It would not be surprising if there were also dialectal differences in the patterns of /x/-production, and it is also worth noting that similar variation between [x], [ɣ], [h], and [ɦ] has been noted in Otuho, and attributed to free variation (Coates, 1985).

In a small number of nominal examples, /x/ is further lenited. For example, the word 'dog SG' is often produced with intervocalic /x/ in careful speech, as in (44a), but in natural speech the fricative is generally elided, as in (44b). Similarly, for 'herders PL', forms with /x/ may be produced in very careful or emphatic speech, as in (44c), but most often the fricative is elided as in (44d). Several speakers have noted that the form in (44c) would be more likely to be heard from older people. This lenition may have relevance to some examples of vowel sequences discussed in 3.6.

(44) a. xíŋɔ̀xʊ̂ dog SG [hf] b. xíŋɔ̀ʊ̂ dog SG [hg]
c. xàjːɔ́xɔ̀k herders PL [hh] d. xàjːɔ́ɔ̀k herders PL [hi]

Among nouns, the lenition of /x/ to ∅ appears to be limited to a few words, but among verbs, it can be seen with somewhat more regularity in specific contexts. For example, the perfective affix /-xi-/ is only produced with the initial fricative in very emphatic speech, or when speakers are being particularly explicit about the morphemic content of a word; in general, this fricative is completely elided, and the remaining vowel then often forms a diphthong with the preceding person-marking affix, as shown in (45a) compared to (45b).

(45) a. èxìlːúm punch 3SG PF [hj] b. eìlːúm punch 3SG PF [hk]

/ʔ/

The glottal stop /ʔ/ occurs only in word-final position, and is only produced prepausally. Despite these restrictions, it is a very common coda consonant, and appears to have significance in the sound system of Lopit. Speakers are extremely consistent in their productions; I am yet to find a word which, when produced in isolation, has a final glottal stop for some speakers and no coda consonant for others, and there is so far only one example in which a different coda consonant (/k/) is used by one speaker, as in (46).

(46) a. mátːáʔ farms PL [hl] b. mátːák farms PL [hm]

Though there is no mention of the glottal stop in Stirtz (2014b), it has been previously noted for Lopit by Turner (2001), and for Lopit as well as Dongotono, Lokoya and Otuho by Vossen (1982). Turner (2001, p. 31) comments that the Lopit speakers he worked with "do not think of the glottal stop as a consonant", as evidenced by their difficulty representing a difference in spelling, but it is quite salient for at least some of the participants in this project. In unprompted discussion, they often note, for a given word, that there is an extra sound at the end, indicating towards their throat to show where it is produced. While alternations and changes from supralaryngeal stops (particularly voiceless stops) to glottal stops are not uncommon crosslinguistically (O'Brien, 2009), in Lopit the glottal stop does not have a clear relationship with other specific consonants (i.e. as an allophone). It clearly contrasts both with its absence, and with the presence of other consonants, including /t/ and /k/, as shown in (47). Turner (2001) similarly found that the glottal stop did not show any clear pattern of alternation with other segments.

(47)
a. lɔ̀bɔ́ɲíʔ white people PL [hn]
b. lɔ́bɔ̀ɲì spinach sp. SG [ho]
c. bɔ̀ɲìt sheep/goat enclosure SG [hp]
d. lɔ̀ɲík snake sp. SG [hq]

Coates (1985, p. 97) speculates that the final glottal stop in closely-related Otuho may be related to tonal phenomena, and observes that it often appears on low-toned syllables; for Lopit, Turner (2001, p. 38) finds a tendency towards co-occurrence with high tones instead, but (as he states) an unconvincing one. In the data for the current study, many examples show that the glottal stop can freely occur with all tones; (48) shows it may be either present or absent on a low-toned syllable, and (49) and (50) show it can be either present or absent on high- and falling-toned syllables. Therefore, there is no apparent correlation between the glottal stop and preceding tone.

(48)
a. ígàɾàʔ spider SG [hr]
b. xìgàɾà clear grass INF [hs]

(49)
a. tɛ́ɾɛ́ʔ hail PL [ht]
b. fɛ́ɾɛ́ spear SG [hu]
c. tɛ̀ɾɛ̂ place SG [hv]

(50)
a. xàlâʔ sides PL [hw]
b. xáláʔ teeth PL [hx]
c. xáná hand, arm SG [hy]

Impressions are that the glottal stop tends to occur more often after [-ATR] vowels, but this is not especially surprising, as [-ATR] vowels seem to occur more often in general; furthermore, there are some specific points related to this which are worth noting. For example, one of the more common number-marking suffixes applied to nouns which are grammatically marked in the plural has the form /-(x)ɪ(ʔ), -(x)iʔ/, as seen in previous examples. The final glottal stop occurs in almost all examples of this suffix, and while the vowel may occasionally be clearly [+ATR], most often it is [-ATR], as in (47a)[11]. However, for the common and segmentally similar number-marking suffix /-(C)i/, which reliably has a [+ATR] vowel and is applied to nouns which are grammatically marked in the singular, as in (51), no examples with a final glottal stop have yet been observed.

(51) a. xàlaî side SG [hz] b. xàlátì tooth SG [ia]

In addition, in the small number of cases in which tone, rather than a segmental morpheme, appears to be the main distinction between a singular and plural noun, one of the pair will have a final glottal stop,[12], as shown in (52). This may be either the plural or the singular form, but the glottal stop does occur on a high-toned syllable in each case.

(52)
a. íkáfútì bat sp. SG [ib] b. ìkàfútíʔ bats sp. PL [ic]
c. xìnè goats PL [id] d. xínéʔ goat SG [ie]
e. jànì tree, fruit SG [if] f. jáníʔ trees, fruits PL [ig]
g. kòn:ìkón:ì camel SG [ih] h. kòn:ìkón:íʔ camels PL [ii]

Examples of these minor correspondences between the glottal stop and morphological patterns hint at the possibility that the glottal stop may have occurred as, or as part of, a segmental morpheme. In the case of the plural suffix noted above, it could also be speculated that the co-occurrence of [-ATR] vowels and the glottal stop is indicative of a natural relatiopnship between the two, given the articulatory affinity between laryngeal constriction and glottalisation. However, as shown in the examples above, the glottal stop freely occurs following [+ATR] vowels as well. At this stage much more exploration will be required before anything further can be said on this topic. Given that the final glottal stop appears to be shared by the Lotuxo languages (and can be found in cognates for which tone and vowel qualities vary, e.g. as in (53)), it seems that if something caused it to arise, it was at a time too far removed from the collection of currently available data for it to be easily retrieved. In sum, then, these observations correspond to Turner's (2001)

[11] At some times it is difficult to be certain of the vowel quality in this environment, as vowels may be quite short preceding the glottal stop, and may sometimes be quite creaky in advance of the closure.

[12] An exception to this is the word 'father', shown later in (119) in 3.4.3.4, for which the difference is tone and, optionally, a diphthongal vowel in one syllable.

findings, and though he preferred not to analyse the glottal stop as a phoneme, the lexical evidence presented here suggests that it is distinctive for at least some speakers of Lopit.

(53)
a. ɛ̀fíʔ be sharp 3SG [ij] b. <ɔ́fìʔ> [Otuho - RV] [ik]
c. xálʊ́ʔ back SG [il] d. <ɛxalʊʔ> [Otuho - CM] [im]
e. tːàmʊ̀ʔ helmet SG [in] f. <atːa̝muʔ> [Otuho - CM] [io]
g. xáláʔ teeth PL [ip] h. <âːlàʔ> [Otuho - HC] [iq]
i. táríʔ evening [ir] j. <átārīʔ> [Otuho - HC] [is]
k. rɛ́ʔ milk [it] l. <álɛ̀ʔ> [Otuho - HC] [iu]

3.3.2 Nasals

Table 3.3: *Examples of nasal contrasts in Lopit, by word position.*

C		Word-initial		Intervocalic		Word-final
m	málá	bleat, roar INF [iv]	ŋàmàʔ	sorghum PL [iw]	xàràm	monkey sp. SG [ix]
n	nàfìtà	carry on back INF [iy]	máná	farm SG [iz]	wːàràn	be alive INF [ja]
nː	nːàŋà	slap INF [jb]	ánːáŋ	slap 1SG [jc]	-	
ŋ	ŋásíʔ	years PL [jd]	màŋât	elders' area SG [je]	bàlàŋ	salt, broth SG [jf]
ɲ	ɲàràt	farm plateau SG [jg]	màɲà	life SG [jh]	ŋìdòɲ	grey monkey SG [ji]

/m/

The voiced bilabial nasal /m/ occurs often, and may occur in all word positions, though it is less frequent in word-final position. It clearly contrasts with other labial consonants, e.g. in (54a) compared to (54b), (54c) compared to (54d), and (54e) compared to (54f). It also contrasts with other nasals, as can be seen in Table 3.3.

(54)
a. móŕó insult INF [jj] b. bɔ̀rɔ̀ be big INF [jk]
c. límá sheep tail SG [jl] d. lìbɛî be good, well INF [jm]
e. xírám play INF [jn] f. ítːàb bribe 2SG [jo]

These findings accord with observations by Stirtz (2014b, p. 9), Turner (2001, p. 22-23), and Vossen (1982, p. 191). Stirtz (2014b, p. 26) found one example of geminate /mː/ in the word 'gum SG for the Lomiaha, Lohutok and Lolongo dialects, as shown in (55a), but it is not present in the corresponding Dorik and Ngutira words collected in that study, as shown in (55b), nor any other words that have been recorded so far in the present study and other work.[13]

(55) a. <imːadɔk> gum SG [S. Lopit - TS] [jp]
b. <màdɔ̂k> gum SG [Ngut., Drk. - TS] [jq]

/n/

The voiced alveolar nasal /n/ is very common in Lopit words, and occurs in all positions. Occurrences of /n/ are increased by its use in a number of frequently occurring morphemes, such as various particles indicating feminine grammatical gender, and several number-marking morphemes. It contrasts with other alveolar consonants, e.g. in (56a) compared to (56b), and (56c) compared to (56d). Though word-final /d/ is very rare, the contrast with /n/ can also be observed in this position, as in (56e) compared to (56f). /n/ clearly contrasts with other nasals, as can be seen in Table 3.3. These findings match those of Stirtz (2014b, p. 9), Turner (2001, p. 22-23), and Vossen (1982, p. 191).

(56) a. nʊ̀ɾà eat powdery food INF [jr] b. dʊ̀ɾà bring (someone) down INF [js]
c. xìnè goats PL [jt] d. xìdɛ̀ʔ top, surface SG [ju]
e. xàlàn be lazy INF [jv] f. aípàd whip 1SG [jw]

/nː/

The geminate alveolar nasal /nː/ is one of four geminate sonorants observed in addition to the alveolar stops /tː/ and /dː/. It is the least common nasal to occur, and one of the less common geminates, but appears both in both medial position, as in (57a) compared to (57b), as well as initial position, as in (57c) compared to (57d). Impressions are that is has a longer closure duration than /n/, and it has been described as a 'heavy *n*' by several Lopit speakers.

(57) a. xínːíŋ listen INF [jx] b. xìnínìŋ shake head INF [jy]
c. nːàŋà slap INF [jz] d. nàŋ 1SG [ka]

[13]The Dorik participants in the current project use a different word, /táríɡɔ̀lìʔ/, to refer to this sticky tree gum, though they are aware of the lexical variant used elsewhere in the Lopit area.

However, (57c) is so far the only reliable example of /nː/ word-initially. Word-initial /nː/ has also been observed for the verb in (58a), but the closure duration for the nasal in this word appears to have variable realisations in inflected forms. In some examples of 1SG inflections, as in (58b), a noticeably long closure is perceived, but in 3SG inflections the closure appears to range from only slightly long (58c) to quite short (58d). In comparison, the nasal for the verb in (57c) is consistently long in all inflected forms recorded with various speakers. The verb in (57a) has a perceptibly long closure in most recorded instances, but in some tokens this is less clear. In general, then, the functional load of /nː/ in verb stems may be limited.

(58) a. nːàxà suckle INF [kb] b. ánːák suckle 1SG [kc]
c. ɛ́nːáxà suckle 3SG [kd] d. ɛ́náxà suckle 3SG[ke]

Other examples of /nː/ are few, but it does very reliably appear in feminine relativisers and demonstratives, such as in (59a) and (59b). These are very high-frequency words in natural speech, particularly because the grammatically unmarked gender is feminine, so these occur more often than the corresponding masculine forms (which have a geminate lateral) presented in 3.3.3. Stirtz (2014b, p. 25) notes that there were no examples of /nː/ for any nouns or verbs in his data, but similarly found examples in relativisers and demonstratives for all dialects but Ngutira. Long nasals and laterals have also been noted in cognate words in Maa (Hollis, 1905).

(59) a. ìnːâŋ this F SG [kf] b. xɔ̀nːâŋ these F PL [kg]

In the present data, examples have also been found in some plural nouns, for example (60a) and (60b) (and see also 'small holes PL' in Figure 3.4). The singular form of each of these ends with a trill, as in (60c) and (60d). It is possible that a suffix of the form /Ci/ is involved in the plural forms, and that the sequence of /r/ and C, which is not otherwise permitted (unless the C is a glide), becomes /nː/ in these words. [14] Corresponding forms of 'valleys, riverbeds PL' collected by Stirtz (2014b, p. 47) for different dialects do not have

[14]There is a number-marking suffix of the form /-ni/, but this lacks the final glottal stop, is only used for marking singular rather than plural, and only applies to animate (usually human) referents, e.g. /xaìdóŋòní/ 'blacksmith SG' compared to /xaìdóŋôk/ 'blacksmiths PL' (from /xìdóŋó/ 'make tools INF').

/nː/, but Turner (2001, p. 25) finds a similar example for 'antelope' <bòr>and 'antelopes' <bònːí>, and notes that at least one dialect uses the plural <wònːí>for <wór>. This is not a productive process; in the current data, the given examples are the only words which show this pattern, and /r/-final nouns otherwise take V-initial number-marking suffixes. However, it certainly appears to be a possibility for at least some speakers, and is similar to the context for some instances of /tː/ discussed earlier. More generally, it seems that while /nː/ is present in Lopit, it has a very limited distribution, and may be of dubious status among verbs. Vossen (1982, p. 191) did not find any examples of /nː/ is his data.

(60)
a. bónːìʔ antelopes sp PL [kh]
b. wónːìʔ valleys, riverbeds PL [ki]
c. bɔ̀r antelope sp. SG [kj]
d. wɔ́r valley, riverbed SG [kk]

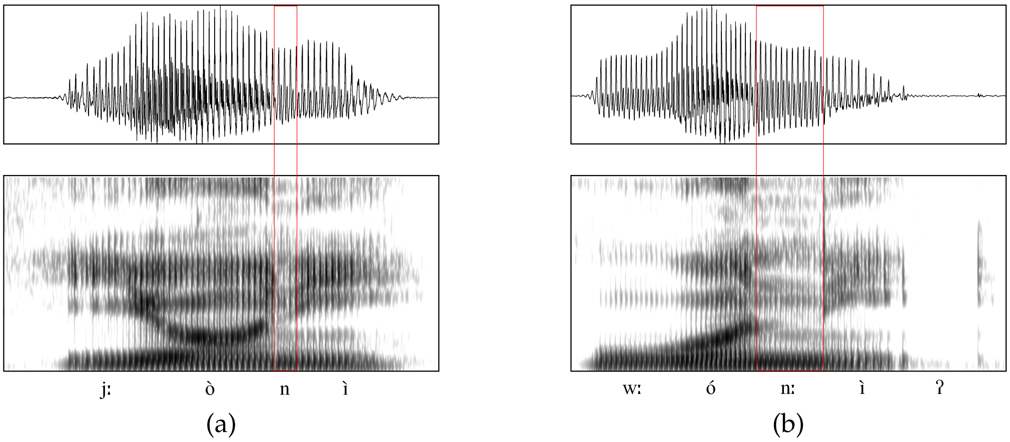


Figure 3.4: *Acoustic waveform and spectrogram of alveolar nasals in /jːònì/ 'hide, skin* SG*' and /wːónːìʔ/ 'small holes* PL*' (dynamic range 50dB, duration 750ms).*

/ɲ/

The palatal nasal /ɲ/ occurs least often among the non-geminate nasals, but is found in all positions. This is similar to observations made by Stirtz (2014b, p. 9), Turner (2001, p. 22-23), and Vossen (1982, p. 191), though Vossen did not find any word-final examples of /ɲ/ in Lopit. /ɲ/ contrasts with other palatal consonants, for example initially in (61a) compared to (61b), medially in (61c) compared to (61d), and finally in (61e) compared to (61f).

(61)
a. ɲát swamp SG [kl]
b. ɟátíʔ vegetables SG [km]
c. xɔ̀ɲɛ̀k eye SG [kn]
d. lɔ̀ɟɛ̀k weaver bird sp. SG [ko]
e. ɔ́xɔ́ɲ bite 3SG [kp]
f. ɔ́xɔ́ɟ scratch 3SG [kq]

It contrasts with other nasals, as can be seen in Table 3.3, and it also contrasts with sequences of /n/ followed by /j/, as in (62a) compared to (62b) (though as discussed in 3.3.4, such sequences are more common at morpheme boundaries, as a result of glide formation, than in monomorphemic words). As for the other palatal consonants /c/ and /ɟ/, impressions are that the palatal nasal has a laminal articulation, involving substantial contact from the blade of the tongue in the region between the alveolar ridge and the palate.

(62)
a. ɟànjâ brooms PL [kr]
b. áɲá eat 1SG [ks]

/ŋ/

The velar nasal /ŋ/ occurs often, and in all positions. It contrasts with other velar consonants, for example initially in (63a) compared to (63b), and medially in (63c) compared to (63d). While there are as yet no examples of the voiced velar plosive /ɡ/ word-finally, the coda contrast can be observed between /ŋ/ and /k/, as in (63e) compared to (63f). As for other nasal consonants, the present findings match those of Stirtz (2014b, p. 9), Turner (2001, p. 22-23), and Vossen (1982, p. 191). The velar nasal is important in several morphemes, for example the counterfactual verbal prefix and perfective verbal prefix.

(63)
a. ŋáɲínì daughter SG [kt]
b. ɡárìɲìn animal tracks PL [ku]
c. lɔ̀ŋɔ̀rɔ̀m termites PL [kv]
d. lɔ́ɡɔ̀rɔ̀ʔ throat SG [kw]
e. xítɛ́ŋ cow SG [kx]
f. fɛ̀tɛ̀k fishing spear SG [ky]

For the word ‘cows PL’, most participants invariably produce a final velar nasal, as in (64a), but one participant instead optionally produces the form in (64b), with nasalisation but no velar closure. This is interesting given that Stirtz (2014b, p. 39) transcribes /xicu/ for the Dorik participant in his study; there may be some lexically-specified variation in the production of final velar nasals in the Dorik area.

(64)
a. xísʊ́ŋ cows PL [kz]
b. xísʊ̃́ cows PL [la]

3.3.3 Liquids

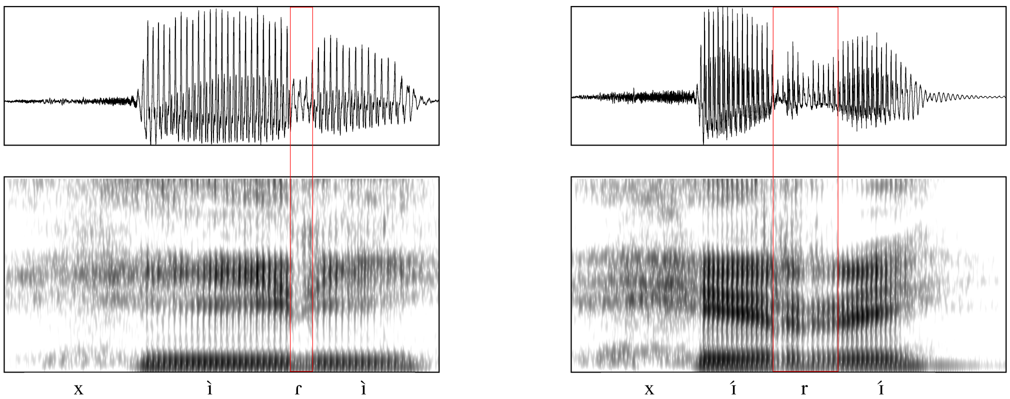
Table 3.4: *Examples of liquid contrasts in Lopit, by word position.*

C	Word-initial		Intervocalic		Word-final	
ɾ	-		áɾá	be 1SG [lb]	-	
r	ràdà	fill gap INF [lc]	áráf	touch 1SG [ld]	fár	daytime [le]
l	lákjéʔ	lice PL [lf]	bàlàŋ	salt, broth SG [lg]	kál	side SG [lh]
lː	lːàxà	release INF [li]	álːáŋ	cross INF [lj]	-	

/ɾ/

There is an alveolar tap /ɾ/ which contrasts with other alveolar consonants; compare, for example, (65a) and (65b) for the contrast with the voiced alveolar stop, and (65c) and (65d) for the contrast with the alveolar trill, as well as other examples in Table 3.4, below, and shown in the spectrogram examples in Figure 3.5.

(65)
a. fɛ́ɾɛ́ spear SG [lk]
b. fɛ́dɛ́ calabash dish SG [ll]
c. xìɾì women's walking stick SG [lm]
d. xìrîʔ to equal, amount to INF [ln]



(a) (b)

Figure 3.5: *Acoustic waveform and spectrogram of rhotics in /xìɾì/ 'women's walking stick* SG*' and /xírí/ 'waterhole* SG*' (dynamic range 50dB, duration 700ms).*

The alveolar tap is not produced word-finally; in instances where it might have occurred, as a result of its position in certain verb stems, it is instead realised as a trill.

Compare, for example, the infinitive verb forms in (66a) and (66b); in perfective inflections, both are realised with a word-final trill, as in (66c) compared to (66d). Though the alveolar tap can occur as the initial consonant of verb stems, it does not appear to be contrastive word-initially, as discussed in more detail below. Vossen (1982, p. 191) records only an alveolar trill, and no tap, while Turner (2001, p. 11) explicitly proposes a contrast between a tap and trill, and Stirtz (2014b, p. 10) notes the presence of both a short and long rhotic.

(66)	a.	bwóró	be white INF [lo]	b.	bɔ̀ɾà	smash, shatter INF [lp]
	c.	òbwór	be white 3SG [lq]	d.	ɔ́bɔ́r	smash 3SG [lr]

/r/

The alveolar trill /r/ also contrasts with other alveolar consonants, for example with the voiced alveolar stop, as in (67a) compared to (67b), as well as initially in (67c) compared to (67d).

(67)	a.	lɔ̀rít	leafy grass sp. [ls]	b.	lódìk	shadow SG [lt]
	c.	ráŋ	bow SG [lu]	d.	dáŋ	all, everyone [lv]

The trill also contrasts with the alveolar tap intervocalically, as shown above and also in (68a) compared to (68b). The trill tends to be produced quite long, and though the tap and the trill differ in manner of articulation, the contrast between these two rhotics could be considered part of the same pattern as the length contrast proposed for other alveolar consonants. Both may also occur in onset clusters followed by a glide, as in (68c) compared to (68d).

(68)	a.	mɔ̀rɔ̂ʔ	beans PL [lw]	b.	móɾó	insult INF [lx]
	c.	xárjàk	breeding male animals PL [ly]	d.	xáɾjàk	fence repairers PL [lz]

As noted above, both rhotics are realised as a trill word-finally. Though both the tap and the trill can occur as the first consonant of a verb stem, for example as shown in the 3SG inflected forms in (69a) compared to (69b), when these stem-initial rhotics occur word-initially in infinitive verb forms, as in (69c) and (69d) (and for various similar verbs), there is limited evidence that they contrast. If these rhotics are word-initial but utterance-medial, following an open syllable, they may sometimes be produced as a trill and tap respectively, but may also both be produced as a trill, or sometimes both may be produced as alveolar approximants. If these rhotics are both word-initial and utterance-initial, they are typically both produced as trills, and sometimes as approximants. The same is true of word-initial rhotics among nouns, and the variation appears to be influenced by both individual and stylistic factors. Turner (2001, p. 13) proposes a word-initial contrast between the tap and the trill based on similar verbal examples, but in the present study, a trill is the most common word-initial realisation of both.[15]

(69)
a. ɔ́ɾɔ́mà wrestle 3SG [ma]
b. ɔ́ɾɔ́mɔ̀ plough 3SG [mb]
c. rɔ̀mà wrestle INF [mc]
d. ɾɔ̀mɔ̀ plough INF [md]

/l/

There is an alveolar lateral approximant /l/, which, as also shown in Table 3.4, contrasts with the rhotics, as well as with other alveolar consonants, for example initially as in (70a) compared to (70b) and (70c), and medially in (70d) compared to (70e) and (70f).

(70)
a. lìxà hunt INF [me]
b. dìxɛî be painful INF [mf]
c. rìxò trade INF [mg]
d. wːʊ̀là jump INF [mh]
e. fʊ̀dà be humid INF [mi]
f. dʊ̀rà bring (someone) down INF [mj]

It is less common word-finally, but contrast with alveolar consonants can still be observed in this position, for example comparing (71a) to (71b) and (71c). In his comparisons of Lopit lexical data across dialects, (Stirtz, 2014b, p. 5) notes that in some words, the southern dialects (Lomiaha, Lohutok, and Lolongo) have /l/ where the the Dorik and Ngutira dialects have /r/. He also notes that in some words, where the Dorik and Ngutira examples have word-initial /l/, the /l/ is absent in corresponding forms for the southern dialects. While this has not so far been investigated, it is frequently suggested by the Dorik participants in the present study to be a sign of the influence of the Otuho language on the southern Lopit varieties.

(71)
a. fàɾâl small axe SG [mk]
b. aípàd whip 1SG [ml]
c. táfár pond SG [mm]

[15]Stirtz (2014b, p. 10) lists this consonant as an alveolar approximant, and as for other long consonants, prefers an analysis of identical segments either side of a syllable boundary rather than contrastive long consonants.

/lː/

As for the alveolar stops, nasal and rhotics, the alveolar lateral also has a geminate counterpart /lː/, which has an audibly longer closure than /l/. It is found medially, as in (72a) compared to (72b), and in (72c) compared to (72d).

(72) a. xìlːáʔ wash INF [mn] b. xìlàʔ thunderstorm SG [mo]
c. xílːím check INF [mp] d. xìlík be cold INF [mq]

It is also found initially, as in (73a) compared to (73b), and (73c) compared to (73d). However, it occurs less often in this position (as well as being infrequent in general).

(73) a. lːɛ̀r ground, open area SG [mr] b. lɛ̀fɛ̀ since, until [ms]
c. lːàɲà cross INF [mt] d. lákjéʔ lice PL [mu]

Nominal examples of initial /lː/ as in (73a) are particularly rare; as noted for other geminates, word-initial occurrences are most often in infinitival verb forms, as in (73c), and (74a), below. Inflected forms of these verbs show that the segment is reliably produced as a geminate across different segmental and tonal contexts, e.g. as in (74b) and (74c).

(74) a. lːùmò punch INF [mv] b. òlːúm punch 3SG [mw]
c. tólːùm punch IMP [mx]

As for /nː/, /lː/ is also found in relativisers and demonstratives (marked for the masculine rather than feminine gender) as in (75a) and (75b).

(75) a. ìlːɛ̂ŋ this M SG [my] b. xʊ̀lːɔ̂ŋ these M PL [mz]

3.3.4 Glides

Table 3.5: *Examples of glide contrasts in Lopit, by word position.*

C	Word-initial		Intervocalic		Word-final
w	wɔ́r	valley, riverbed SG [na]	áwà	submerge 1SG [nb]	-
wː	wːòr	small hole SG [nc]	xàwːàʔ	arrows PL [nd]	-
j	jɔ́xɛ́ʔ	ears PL [ne]	xíjàjàʔ	porcupine SG [nf]	-
jː	jːònì	hide, skin SG [ng]	íxájːá	pumpkin leaves PL [nh]	-

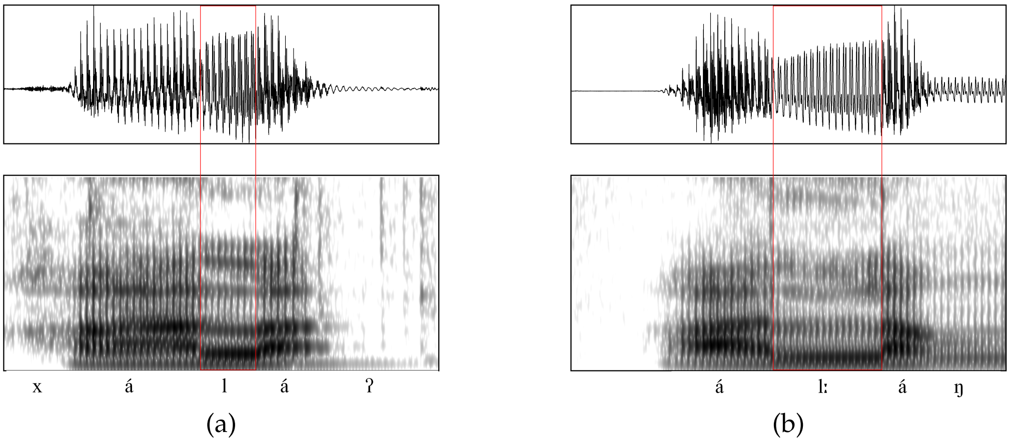


Figure 3.6: *Acoustic waveform and spectrogram of alveolar laterals in /xáláʔ/ 'teeth* PL*' and álːáŋ/ 'cross* 1SG*' (dynamic range 50dB; 60dB, duration 500ms).*

/w/

The labial-velar glide /w/ appears word-initially and intervocalically (shown in Figure 3.7a), and also appears often in consonant clusters. It contrasts with other labial and velar consonants, for example initially as in (76a) compared to (76b) and (76c), and medially in (76d) compared to (76e) and (76f).

(76)
a. wáxá distant bushland SG [ni] b. bàxà hit INF [nj]
c. gàlà government official SG [nk] d. xìwːàxà meet INF [nl]
e. ìbàtìʔ granary SG [nm] f. xìgàɾà clear grass INF [nn]

Consonant clusters can occur as syllable onsets, and /w/ is permitted as the second segment in these clusters and can be observed following a range of consonants. Compare, for example, the verbs in (77a) and (77b).

(77) a. ɔ́bɔ́r smash, shatter 3SG [no] b. òbwór be white 3SG [np]

Evidence from some singular/plural alternations indicates that some instances of clusters involving glides may arise through glide formation, for example comparing the unmarked plural noun in (78a) to the form in (78b) with singulative suffix /-o/, and the unmarked singular noun in (78c) to the form in (78d) with the plural suffix /-a/.

(78)
a. mórúʔ stones PL [nq] b. mórwó stone SG [nr]
c. kɛ̀bʊ̀ hoe SG [ns] d. kɛ̀bwâ hoes PL [nt]

However, the opposite may also occur, with /w/ in a monomorphemic noun as in (79a) and /u/ in the morphologically marked form, as in (79b). These patterns require further research, and are complicated by the irregularity of number marking in Lopit. Both likely interact with other prosodic considerations in ways that are not yet clear. It is worth noting that where clusters involving /w/ occur in verb stems, the cluster appears to be preserved across inflected forms, as seen earlier in (66a) and (66c).

(79) a. xìɾwòʔ bamboo PL [nu] b. xìɾúòtí bamboo SG [nv]

In the analysis presented by Turner (2001, p. 51-56), segments corresponding to /w/ in complex onsets in the present data are transcribed as vowels rather than consonants, for orthographic simplicity and because the analysis disprefers consonant clusters, but Turner (2001, p. 56) acknowledges that in terms of syllable structure, they are more consonantal at least in onsets. Stirtz (2014b, p. 13-16) interprets them as consonant segments, but also posits that glides occur in syllable codas,[16] in an analysis that disprefers diphthongs and vowel sequences. These matters are discussed further in 3.4.2 and 3.6.

/wː/

There is also a geminate labial-velar glide /wː/ among the geminate sonorants. Though length-based contrasts are not widely attested among glides crosslinguistically, as noted in 2.2.4 a contrast of this sort has also been suggested for some closely-related languages. However, little is known about the phonetic nature of geminate compared to singleton glides, and as discussed further in 5.2, there some debate over the extent to which length differences among glides are reliably perceived and produced, given the high sonority of these segments (as can be seen in Figure 3.7). Impressionistically, constriction duration is a major cue to the difference between the two, but there are also some audible differences in the quality of /wː/ compared to /w/ which suggest the constriction may be narrower for the geminate.

Though /wː/ appears to be less common than singleton /w/, the two clearly contrast both intervocalically and word-initially. Examples of word-initial contrasts include (80a)

[16] Turner also suggests that glides can occur as codas, and proposes no diphthongs, but at the same time suggests that they are not really consonantal in this context.

compared to (80b), and examples of medial contrasts include (80c)[17] compared to (80d).

(80)
a. wːɔ̀r small hole SG [nw] b. wɔ́r valley, riverbed SG [nx]
c. léwːá gazelle sp. SG [ny] d. rɛ̀wà husbands PL [nz]

However, /wː/ is not particularly common word-initially, and most word-initial examples are, as for /tː/, in infinitival verb forms. The geminate is then maintained in inflected forms, as seen in the examples in (81).

(81)
a. wːàràn be alive INF [oa] b. wáxán want INF [ob]
c. áwːár be alive 1SG [oc] d. áwák want 1SG [od]

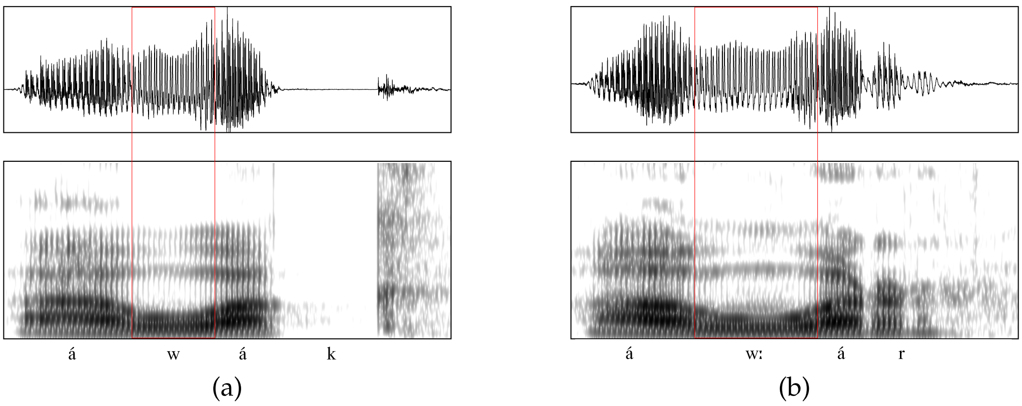


Figure 3.7: *Acoustic waveform and spectrogram of labial-velar glides in /áwák/ 'want* 1SG*' and /áwːár/ 'be alive* 1SG*' (dynamic range 50dB, duration 600ms).*

This can also be observed in inflected nouns, for example in the different tonal contexts of absolutive compared to nominative forms in (82).

(82)
a. ìwːâʔ wings PL [oe] b. íwːàʔ wings PL NOM [of]
c. àwːáŋàʔ red monkeys PL [og] d. áwːàŋàʔ red monkeys PL NOM [oh]

The geminate labial-velar glide has also been observed by Vossen (1982, p. 191-192), Turner (2001, p. 11-14), and Stirtz (2014b, p. 10-11); all discuss the difference between the two glides in terms of consonant length, but Turner also uses the broad terms 'strong' and 'weak' to group consonants, in order to encompass certain obstruent and fricative relationships. Both Vossen and Stirtz find only medial examples of /wː/, and given this,

[17] The initial lateral in this word is sometimes produced quite long; it may be /lː/ for at least some speakers.

Stirtz prefers to analyse this and other geminates as sequences of the same consonant occurring either side of a syllable boundary, but Turner presents examples of /wː/ initially as well as medially, for some of the same words noted here. Turner (2001, p. 11) notes that the long glides are also characterised by frication, but this has not been found in the present data. However, frication would also be indicative of greater constriction. Lopit speakers are very aware of the difference between /wː/ and /w/, describing them as 'heavy' and 'light' respectively, in the same way as for differences between obstruents such as /tː/ and /t/.

/j/

There is a voiced palatal glide /j/ which is found word-initially and word-medially (shown in Figure 3.8a). It contrasts with other palatal consonants, for example initially in (83a) compared to (83b) medially in (83c) compared to (83d).

(83) a. jànì tree SG [oi] b. ɟànî broom SG [oj]
c. xìjò people PL [ok] d. xìɟò say INF [ol]

As for the labial-velar glide, the palatal glide may occur as the second segment in consonant clusters, following a range of consonants. Compare, for example, (84a) to (84b).

(84) a. bɔ́lɔ́rɔŋ hippopotamus SG [om] b. bòljòŋ peacefully [on]

Many instances of palatal glides in clusters are clear examples of glide formation at morpheme boundaries, for example comparing the final vowel /-i/ in singular nouns such as in (85a) and (85b) to the presence of the glide in their plural forms with suffix /-o/, as in (85c) and (85d).

(85) a. kòrì giraffe SG [oo] b. dómí knife SG [op]
c. kòrjò giraffes PL [oq] d. dòmjô knives PL [or]

Some are clearly part of the stem rather than a result of morphological processes, as in the monomorphemic words in (86a) and (86b), though where consonant-glide sequences occur in monomorphemic words, a labial-velar glide is much more likely.

(86) a. xìmjɛ̀k pus [os] b. ŋádjéf tongue SG [ot]

Examples of contrast between sequences such as these and articulatorily similar consonants like the palatal nasal can be found, such as the demonstrative in (87a) compared to the noun in (87b).

(87) a. njà that F [ou] b. ɲáʔ udder SG [ov]

However, such examples are notably scarce when looking at verbs, for which the stem-initial consonant slot reliably exhibits other contrasts. For example, /nj/ occurs stem-initially in the verb in (88a), but so far examples of stem-initial /ɲ/ in verbs are found only in similar, but not identical, vowel environments, e.g. comparing (88a) to (88b) and (88c). This is perhaps not particularly surprising, given that the use of /j/ in onset clusters appears to be more restricted in general, compared to /w/ (see also 3.6.3), but the similarity of /nj/ to /ɲ/ may also influence the distributional patterns of /nj/ (whereas /ɲ/ can occur in all segmental contexts).

(88) a. énjémà be skinny 3SG [ow] b. ɛ̀ɲíl be smooth 3SG [ox]
c. ɛ̀ɲár be good 3SG [oy]

While Turner (2001, p. 51-56) and Stirtz (2014b, p. 13-16) both similarly observe that /j/ can occur in onset clusters, as noted above for /w/, they also describe such segments as able to occur as syllable codas, either alone or as the first segment in a complex coda. This differs from the analysis in the present work, which posits contrastive diphthongs to account for such sequences instead, discussed in more detail in 3.4.2 and 3.6. Intervocalically, some instances of /j/ may be phonetic glides occurring as a result of transitions between close-front vowels and non-close vowels, for example in the monomorphemic words in (89a) and (89b).

(89) a. bíjɔ́ŋ fruit tree sp SG [oz] b. íjèk chick SG [pa]

However, many examples of /j/ following /i, ɪ/ are unambiguously part of the word stem; for example in (90a), the 2SG prefix /i-, ɪ-/ precedes /j/ as the first consonant of a Class 1 verb, while for the Class 2 verb in (90b), recalling that Class 2 verbs always begin with a close vowel followed by a consonant, the same prefix /i-, ɪ-/ precedes /ij/ (and in these cases, coalesces with the initial vowel).[18]

(90) a. íjɛ́fà lash, chop 2SG Pb b. íjèn know 2SG Pc

Initial sequences of /xi, xɪ/ are very common elements of both nouns and verbs in Lopit,[19], meaning that all consonants occur often after close front vowels.

/jː/

As for the labial-velar glides, a length-based contrast is proposed for the palatal glides, and geminate palatal /jː/ is proposed. Constriction duration is an audible difference between /jː/ and singleton/j/, with some additional possible differences in quality. As for similar contrasts elsewhere in the consonant inventory, including the labial-velar glides, Lopit speakers often refer to the former as 'heavy' and the latter as 'light'. The waveforms and spectrograms shown in Figure 3.8 show that, as for the labial-velar glides, the boundaries between these segments and adjacent vowels are much less clearly defined compared to the earlier examples of geminate stops, a matter discussed in more detail in Chapter 5 as these segments are explored further with phonetic data.

/jː/ contrasts with the singleton palatal glide both word-initially and word-medially. As for other geminates, most word-initial examples are found in infinitive verb forms which can occur on their own in certain constructions. For example, the contrast can be observed in initial position in (91a) compared to (91b), and medially when these verbs are inflected as in (91c) compared to (91d).

(91) a. jːɛ̀tà pull INF Pd b. jɛ̀fà lash, chop INF Pe
c. ɛ́jːɛ́tà pull 3SG Pf d. ɛ́jɛ́fà lash, chop 3SG Pg

The palatal glide /jː/ also clearly contrasts with the voiced palatal stop, for example as in (92a) compared to (92b), or (92c) compared to (92d).

[18]For this particular verb, the glide is often, but not consistently, perceptibly long; it may be /jː/ for some speakers.

[19]These are thought to originate from historical prefixes in the Nilotic family, which are in most cases no longer morphologically productive; they are not found in the Western Nilotic branch, but reflexes with similar forms are observed across Eastern and Southern Nilotic languages (J. H. Greenberg, 1981; Dimmendaal, 1983c).

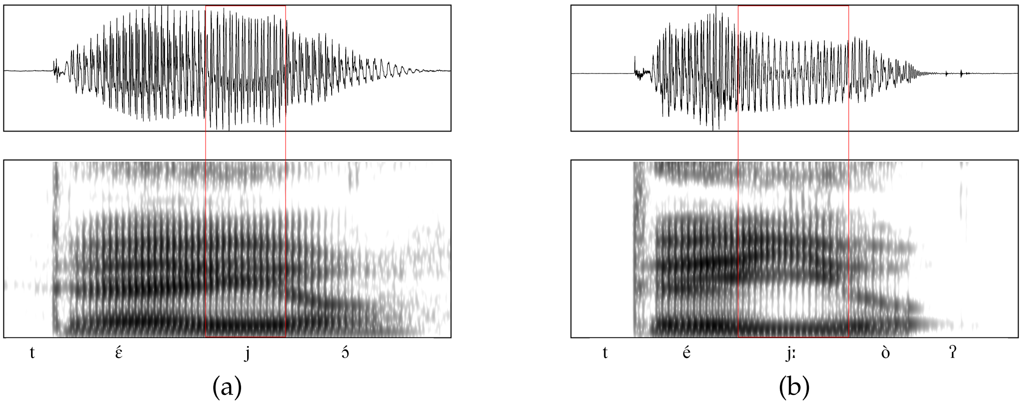


Figure 3.8: *Acoustic waveform and spectrogram of palatal glides in /tɛ́jɔ́/ 'die* IMP*' and /téjːòʔ/ 'cry* IMP*' (dynamic range 50dB, duration 500ms).*

(92)
a. íjːò cry 2SG [ph]
b. xìɟò say INF [pi]
c. xòjːèk wood PL [pj]
d. lɔ̀ɟɛ̀k weaver bird sp. SG [pk]

Vossen (1982, p. 191-192), Turner (2001, p. 11-13) and Stirtz (2014b, p. 10-11) have observed a similar contrast, and while Vossen and Turner each provide word-initial examples of geminate /jː/, data collected by Stirtz includes only medial examples, so as in similar cases, the proposed analysis is of sequences of /j/ across syllable boundaries, rather than contrastive /jː/. All three authors discuss the difference in terms of consonant length, though Turner (2001, p. 11) adds that "[a]s well as being longer than /j/, /jː/ is realised with slightly more friction". This has not been observed in the present study.

3.4 Vowels

3.4.1 Monophthongs

In the present data for the Dorik dialect of Lopit, impressions are of nine contrastive monophthongs. A representation of the vowel qualities, based on auditory impressionistic analysis, is shown in Table 3.6, and I return to a discussion of the vowel qualities as the subject of experimental study in Chapter 4. While true minimal pairs are uncommon, there is good evidence that these vowels all contrast. Some examples are shown in Table 3.7, and throughout this section. Phonological evidence, particularly relating to the vowel harmony process discussed in 3.4.3.1, indicates that these vowels fall into two sets; one consisting of /i, e, o, u/ and another consisting of /ɪ, ɛ, ɔ, ʊ, a/. The vowels of the former have, impressionistically, a closer quality than corresponding vowels in the latter.

It is suggested that the phonological feature 'Advanced Tongue Root' distinguishes these two sets of vowels, and in this chapter, and later chapters, the label [+ATR] has been used to refer to the former set, and [-ATR] to refer to the latter, given that the vowel system proposed here has much in common with vowel systems typically described as drawing on this feature. However, at this stage the feature is used without any claim that the vowels labelled [+ATR] are necessarily articulated with a more anterior tongue root position. Previous work introduced in 2.3.1 and discussed in more detail in 4.2 has shown that there are various acoustic and articulatory correlates of contrasts described with phonological feature [ATR], despite auditory and phonological similarities in such systems across languages. The acoustic and articulatory correlates of the proposed distinction in Lopit need to be verified experimentally, and this is the focus of Chapter 4.

In Lopit, there is a general tendency for both monomorphemic and morphologically complex words to exhibit vowels of the same ATR specification, though this is mediated by various factors noted in relation to the operation of vowel harmony. Of the nine proposed monophthongs, each non-open vowel of the [-ATR] set has a counterpart of similar height, backness and rounding in the [+ATR] set, and the pairs /i, ɪ/, /e, ɛ/, /o, ɔ/ and /u, ʊ/ have significance for the harmony processes discussed below. The open vowel /a/ patterns with the [-ATR] vowels, for reasons also discussed below, and does not appear to have a [+ATR] counterpart. There is no evidence of a length contrast among vowels in Lopit. A 9-vowel inventory with no length contrast is very typical of the non-Bari Eastern Nilotic languages, as discussed in 2.3.

/i/ and /ɪ/

The close front unrounded vowel /i/ is classed as [+ATR], and the near-close near-front unrounded vowel /ɪ/ as [-ATR]. Both occur in all word positions, and given that there are a large number of inflectional and derivational morphemes involving /i/ and

Table 3.6: Lopit monophthong inventory (impressionistic)

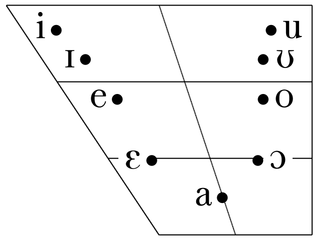


Table 3.7: *Examples of monophthong contrasts in Lopit, grouped by [ATR] specification.*

V		[+ATR]	V		[-ATR]
i	xìrì	walking stick SG [pl]	ɪ	xírí	waterhole SG [pm]
e	xìxélèʔ	be blind INF [pn]	ɛ	íxɛ́rɛ́k	turtle SG [po]
o	xòfwòʔ	flour SG [pp]	ɔ	xɔ́tɔ́	blood SG [pq]
u	xùrêʔ	some F [pr]	ʊ	xʊ̀rɛ̀	thirst SG [ps]
			a	xàtâ	tamarind SG [pt]

/ɪ/, both are found frequently in all these positions. While CV syllables are preferred in Lopit, V syllables do occur, including word-initially, and /i/ and /ɪ/ are most common is this context. Examples of contrast between [+ATR] /i/ and [-ATR] /ɪ/ include (93a) compared to (93b), and (93c) compared to (93d). As discussed further in 3.4.3.1, /ɪ/ also has the allophone [i] as a result of ATR harmony processes.

(93) a. xíɲáŋ crocodile SG [pu] b. xíɲáŋ trick INF [pv]
c. jàmìtà re-marry INF [pw] d. jàmìtà yawn INF [px]

Interestingly, examples of contrast can also occasionally be found in the prefix vowel on Class 2 verbs, even when they share the same stem vowel, for example as seen in (94a) compared to (94b), both of which have [-ATR] /a/ in the stem. The ATR specification of this verb class marker, which is common across Eastern and Southern Nilotic languages, is assumed to show predictable alternations depending on the ATR specification of root vowels (Dimmendaal, 1983c), but in a small number of examples from Lopit this is not the case.

(94) a. xìcàk smash INF [py] b. xìcàk start INF [pz]

/e/ and /ɛ/

The close-mid front unrounded vowel /e/ has been classed as [+ATR], and the open-mid front unrounded vowel /ɛ/ as [-ATR]. Both are found in all word positions, but do not occur word-initially on nouns; most word-initial occurrences are verbs marked with the 3SG person-marking prefix /ɛ-, e-/. [-ATR] /ɛ/ occurs much more often than its [+ATR] counterpart /e/, but /ɛ/ also has the frequently-occurring allophone [e], which results from vowel harmony processes as discussed in 3.4.3.1. Examples of contrast between /e/ and /ɛ/ include (95a) compared to (95b), and (95c) compared to (95d). A mid-vowel assimilation process also causes /ɛ, e/ in prefixes and clitics to be realised as [ɔ, o] when followed by a syllable with a back vowel or labial-velar glide, as described further in 3.4.3.2.

(95)
a. mérjéʔ red ochre [qa]
b. mɛ́djɛ́ʔ spinach sp. SG [qb]
c. xìtèmí front SG [qc]
d. xìtɛ̀nà gossip INF [qd]

The difference between [+ATR] /e/ and [-ATR] /ɪ/ can sometimes be difficult for non-native ears to perceive when new words are encountered. This has often been noted in various other studies of ATR systems, including those of Nilotic languages (as noted in 2.3, and discussed further in 4.2). However, the Lopit participants in this study are very clear on which words require orthographic 'i' (which is used for both /i/ and /ɪ/), and which should have orthographic 'e' (which is used for both /e/ and /ɛ/), and are quick to correct my transcriptions on occasions when I have noted /e/ in place of /ɪ/. The contrast between /ɪ/ and /e/ is supported by various examples of these two vowels occurring in similar environments, for example in (96a) compared to (96b)[20], and the monomorphemic words in (96c) compared to (96d). No true minimal pairs have been recorded; given the tendency for [+ATR] vowels to prefer the company of other [+ATR] vowels, as described in 3.4.3.1, [+ATR] /e/ and [-ATR] /ɪ/ are very unlikely to occur in words which are otherwise segmentally identical.

[20]The final vowel /i/ in this example is not a singulative suffix (which would suggest that /e/ was a result of vowel harmony here) - the singulative affix is /xi-/, and /e/ is also present in the corresponding plural /méríʔ/.[qe]

(96) a. xɔ̀míɾí spinach sp. SG [qf] b. xíméɾì bell SG [qg]
c. kʊ̀ɾìʔ cucumber sp. PL [qh] d. xùɾêʔ some F [qi]

/o/ and /ɔ/

The close-mid back rounded vowel /o/ has been classed as [+ATR], and the open-mid back rounded vowel /ɔ/ as [-ATR]. As for the front mid vowels, they do not occur word-initially on nouns.[21] They also do not occur contrastively in word-initial position for verbs, but [ɔ, o] can occur as word-initial allophones of the front mid vowels in the 3SG person-marking prefix /ɛ-, e-/ (see 3.4.3.2). Impressions are that [-ATR] /ɔ/ occurs somewhat more often than [+ATR] /o/, though /o/ is important in several affixes, such as the plural suffix /-o/. /ɔ/ also has the allophone [o] as a result of vowel harmony (3.4.3.1), and potentially preceding geminate labial-velar glides (3.4.3.3). Examples of contrast between /o/ and /ɔ/ include (97a) compared to (97b), and (97c) compared to (97d).

(97) a. móɾó insult INF [qk] b. mɔ̀rɔ̂ʔ beans PL [ql]
c. xíbó gazelle sp. SG [qm] d. xìbɔ̀ reject INF [qn]

/u/ and /ʊ/

The close back rounded vowel /u/ has been classed as [+ATR], and the near-close, near-back rounded vowel /ʊ/ as [-ATR]. Both are found medially and finally, but never initially. /ʊ/ also has [u] as an allophone under vowel harmony (see 3.4.3.1). Examples of contrast between /u/ and /ʊ/ include (98a) compared to (98b), and (98c) compared to (98d).

(98) a. fúr all [qo] b. fʊ́r dust [qp]
c. ítúlú tell secret INF [qq] d. ítʊ̀lʊ̀ʔ brain SG [qr]

/ʊ/ may be somewhat more common than /u/, but /u/ is important in some affixes, for example the ventive suffix /-u/. When the ventive suffix is attached to a verb stem ending in a close front vowel, the close front vowel becomes a glide, and /u/ is realised

[21] The only possible exception in data collected so far is the word /ɔ̀tʊ́rʊ̀k/, which was tentatively suggested as a possible plural for /tʊ́ɾɛ́ná/ 'flower SG'[qj], but accompanied by the comment that people don't really use a plural for this, and that the suggested form might be an Otuho word.

with a strikingly different quality, approaching [ʉ] and with significant lip rounding (to the extent that a transcription such as [ʉw] would not be inappropriate). This can be seen in (99a) compared to (99b). There is some evidence of the same pattern where there is a sequence of a close vowel, singleton labial-velar glide, and a close back vowel; for example, the stem for 'termite mound' seems to have a sequence of this sort, as seen in (99d) with the addition of the plural suffix /-soʔ/, but in the morphologically unmarked singular, a [jʉ] sequence occurs instead. These may well be part of the same process, if the ventive suffix /-u/ is shown to have a glide inserted when it follows vowels. However, the few examples of these variants need to be supplemented with more data in order to understand both the phonological process and the nature of the resulting articulatory sequence.

(99)
a. eìtínà return 3SG [qs]   b. eìtjʉ̂ return 3SG VEN [qt]
c. kjʉ̀ termite mound SG [qu]   d. kìwûsòʔ termite mounds PL [qv]

As for the close-mid [+ATR] vowel /e/ and the near-close, near-mid [-ATR] vowel /ɪ/, the difference between /o/ and /ʊ/ can at times be difficult for a learner of Lopit to perceive, particularly in contexts such as when they precede rhotics and nasals. However, this is not a challenge for Lopit participants in this project; they are easily able to identify which words are best written with orthographic 'o' (which is used for /o/ and /ɔ/), and which are best written with orthographic 'u' (which is used for both /u/ and /ʊ/), and various examples show that /o/ and /ʊ/ can occur in similar segmental environments, e.g. the monomorphemic words in (100a) compared to (100b), and (100c) compared to (100d). As for /e/ and /ɪ/, the vowels /o/ and /ʊ/ are unlikely to be found surrounded by identical segments, given the general tendency for [+ATR] and [-ATR] vowels not to co-occur within a word.

(100)
a. xítʊ́ bad luck charm SG [qw]   b. xìtó child SG [qx]
c. kʊ̀ɾìʔ cucumber sp. PL [qy]   d. kòɾì giraffe SG [qz]

/a/

The open central vowel /a/[22] occurs often in all contexts. Like /i/ and /ɪ/, it can occur word-initially on nouns, but it is much less common in this context compared to the close front vowels. Word-initial occurrences of /a/ are more often found in verbs, for which /a-/ is important as the 1SG person-marking prefix. It is also used in a number of other affixes. It clearly contrasts with the open-mid [-ATR] vowels /ɛ/ and /ɔ/, as shown in (101).

(101)
a. bàrà keep cattle INF [ra]
b. bɛ̀rá be old, stay long INF [rb]
c. bɔ̀rà smash, shatter INF [rc]

/a/ has been classified as a [-ATR] vowel based on the phonological evidence discussed further in 3.4.3.1, and differs from the other [-ATR] vowels in that it does not appear to have a [+ATR] counterpart, such as /ə/, either as a contrast or as a significant allophone arising in vowel harmony contexts. This is typical of the non-Bari Eastern Nilotic languages. While both Vossen (1982) and Turner (2001) list both a [+ATR] and a [-ATR] open vowel for Lopit, this may be for practical reasons given the indications of vowel harmony; both note that they seem to be phonetically indistinguishable. For closely-related Otuho, some authors propose one open vowel while others propose two, as discussed in 2.3.2.

As noted earlier, there is a general tendency for both monomorphemic and morphologically complex words to exhibit vowels of the same ATR specification (except in the morphophonological contexts discussed in 3.4.3.1), but /a/ can freely occur with vowels of either specification, as shown in the nouns in (102a) and (102b),[23] and the verb forms in (102c) and (102d).[24]

(102)
a. xárí rod, switch SG [rd]
b. xárɪ́ river SG [re]
c. rìtà be missing INF [rf]
d. rɪ̀tà tear INF [rg]

[22] While the vowel quality may be more accurately transcribed as /ɐ/, I have used /a/ in keeping with widespread practice.

[23] Example spectrograms for these words can be seen in Figure 4.1.

[24] The rhotic in these verbs is a tap in the stem, as evidenced by inflected forms, but as noted both taps and trills are produced as trills word-initially.

3.4.2 Diphthongs

A number of diphthongs are also present in Lopit, as shown in the examples in Table 3.8. Though diphthongs with vowel targets corresponding to both [+ATR] and [-ATR] vowel qualities are noted, the functional load of the contrast between the two is likely quite low. For /aʊ/, the word shown is the only example found among nouns, but a diphthong of a similar quality is not uncommon when the ventive suffix /-u/ is attached to verb stems ending in an open syllable, for example as shown in (103a) compared to (103b). The nominal example probably derives from the ventive-marked form of a verb which is likely related, shown in (103c) compared to (103d), though this does not appear to be a regular process as no other nominal examples of this sort have been noted so far.[25]

Table 3.8: *Examples of diphthong contrasts in Lopit, grouped by [ATR] specification.*

V	[+ATR]		V	[-ATR]	
ei	ɟeì	how [rh]	ɛɪ	ìtɛì	2PL [ri]
ai	xaíʔ	rain SG [rj]	aɪ	maíʔ	fires PL [rk]
oi	ìmoìʔ	rhinoceros SG [rl]	ɔɪ	ìxɔì	road SG [rm]
			aʊ	xòjːaʊ̀ʔ	wild food [rn]

(103) a. ítílàʔ wait IMP [ro]
b. ítílaú wait IMP VEN [rp]
c. áxójːà forage 1SG [rq]
d. áxójːaú forage 1SG VEN [rr]

While diphthongs are attested in monomorphemic words, and a small number of verb stems, in many cases they arise at morpheme boundaries. For example, rising diphthongs are formed when person-marking prefixes of the form V- are attached to a V-initial Class 2 verb stem, as well as when number-marking morphemes involving close-front vowels are attached to vowel-final noun stems, as discussed in 3.4.3.4. However, as also discussed in 3.4.3.4, for some words, produced by some speakers, the two targets of these derived diphthongs may coalesce into a single target, which may in turn have ramifications for vowel harmony processes.

[25] At this stage impressions are that this ventive suffix is [+ATR], but further testing of this and its (V)CV allomorphs is required.

As noted earlier, both Turner (2001) and Stirtz (2014b) prefer analyses positing coda glides in Lopit, rather than contrastive diphthongs. Many examples transcribed with coda glides in their data correspond to examples transcribed with rising diphthongs in the present study, suggesting that the observed structures are similar, even if the interpretation differs. In the present data, there is also evidence of vowel sequences, in which each vowel may be produced as a syllable nucleus, discussed further in 3.6.

3.4.3 Phonological processes affecting vowels

3.4.3.1 ATR harmony

Lopit vowels undergo a vowel harmony process which is fairly typical of Nilo-Saharan languages with similar inventories of monophthongs, and of 9-vowel ATR systems more generally (Casali, 2008). [+ATR] is the dominant feature, and the presence of [+ATR] vowels at the right edge of a word will cause preceding [-ATR] vowels to be realised as their [+ATR] counterparts. For example, the morphologically unmarked singular in (104a), with the addition of the plural suffix /-i(ʔ)/, is realised with [+ATR] vowels in the plural in (104b), and the morphologically unmarked plural in (104c) is realised with [+ATR] vowels with the addition of the singulative suffix /-i/, as seen in (104d).

(104) a. xʊ̀lːʊ́k hyena SG [rs] b. xùlːúxíʔ hyenas PL [rt]
c. sɔ̀xɔ̂t coconuts PL [ru] d. sòxótí coconut SG [rv]

In addition to suffixes, [+ATR] vowels in stems also trigger the process. For example, the verbs (105a) and (105b) have vowels with differing ATR qualities in the initial syllable of the stem, and when each is inflected with the 3SG prefix /ɛ-/, the prefix remains [-ATR] in (105c), and is realised as [+ATR] /e-/ when followed by the [+ATR] stem vowel, /i/, in (105d).

(105) a. ɾìtà tear INF [rw] b. ɾìtà be missing INF [rx]
c. ɛ́ɾítà tear 3SG [ry] d. éɾítà be missing 3SG [rz]

[-ATR] vowels never trigger vowel harmony, which means that although there is a tendency for all vowels in a word, and any preceding clitics, to agree in either [+ATR] or [-ATR] specification, it is possible for both to co-occur, resulting in disharmony. For example, the plural suffix /-ɟɪn/ has a [-ATR] vowel, and when suffixed to a noun which also has [-ATR] vowels, such as (106a), there are no changes to vowel quality, as shown in (106c). If the same suffix is attached to a noun with [+ATR] vowels, such as (106b), there is also no change for any vowels, and the resulting plural shown in (106d) therefore has vowels from each ATR category.

(106)
a. bɔ́ŋɔ́ piece of clothing SG [sa]
b. ìxùlóʔ calabash SG [sb]
c. bɔ̀ŋɔ̀ɟɪ̀n clothing PL [sc]
d. ìxúlòɟɪ̀n calabashes PL [sd]

As is typical in a 9-vowel ATR system with only one open vowel, /a/ does not participate in the vowel harmony. In 3.4.1, it has been classified as a [-ATR] vowel, because it patterns with the [-ATR] vowels in various ways. For example, a verb containing /a/ in the initial syllable, such as (107a), will be realised as in (107b) when inflected for 3SG; the prefix /ɛ-/ remains [-ATR], as it does when preceding other [-ATR] vowels. However, unlike other [-ATR] vowels, /a/ does not have a [+ATR] counterpart. In (107c), both vowels are [-ATR], and with the addition of the singulative suffix /-i/, the realisation is as in (107d), with harmony processes causing /ɛ/ to become [e], but the preceding /a/ remains unchanged. In fact, the open vowel /a/ blocks the vowel harmony from spreading any further towards the left edge of the word, and this is another possible source of disharmony. For example, in (107e), all vowels are [-ATR], and with the addition of the [+ATR] plural suffix /-i(ʔ)/, vowel harmony causes /ɔ/ to be realised as [o], there is no change for /a/, and the /ɪ/ preceding /a/ also remains unchanged, as shown in (107f).

(107)
a. bàxà hit INF [se]
b. ɛ́bák hit 3SG IPV [sf]
c. xàtːɛ̀l eggs PL [sg]
d. xàtːélí egg SG [sh]
e. xɪ́tábɔ́k animal trap SG [si]
f. xɪ̀tàbóxí animal traps PL [sj]

For some verbs which appear to have a consonant-final stem, forms such as the imperfective, as well as infinitival forms, have a final vowel which is either /a/ or /o/. The patterns determining the use of one over the other are not yet clear (Moodie, in press), but there are indications that the suffix (if indeed it is a suffix) tends to be /a/ on stems with [-ATR] vowels and /o/ on stems with [+ATR] vowels (e.g. as in possible examples (97a) and (101)). If this is the case, it could be interpreted as one potential example of progressive in addition to regressive harmony operating in Lopit, but with [o] as a [+ATR] allophone of /a/, which does not otherwise occur. A similar process has been noted for Maa (e.g. Quinn-Wreidt, 2013, pp. 8–9). Given that for Lopit, both the morphosyntactic and phonological status of /a/ and /o/ in these specific contexts is not yet fully resolved, and the verb stem is not always easy to unambiguously determine, this is only speculation at this point, but of interest in ongoing research.

In existing discussions of Lopit phonology, ATR harmony has only been mentioned in passing. Vossen (1982, p. 193) observes that vowel harmony "definitely plays an important role" and that "[e]xamples of category shift are rather frequent ... especially between singular and plural". Turner (2001, p. 41) explicitly states that Lopit has a vowel harmony system on the basis of ATR, and tentatively suggests some examples of possible right-to-left spreading of ATR properties. Furthermore, although Turner classes /a/ as having both [+ATR] and [-ATR] variants because it can occur with vowels in each set, he notes the likelihood that there is in fact only one phonemic low vowel whose behaviour in relation to ATR processes is unclear. The present data expand on the aforementioned observations, but differ from findings by Stirtz (2014b), whose work makes no mention of ATR harmony given that the analysis of the vowel system does not include a contrast on the basis of ATR.

3.4.3.2 Mid-vowel assimilation

In addition to ATR harmony, a separate process of assimilation operates on mid-vowels. When syllables containing the mid front unrounded vowels /ɛ/ or /e/ occur as prefixes or clitics preceding syllables containing back rounded vowels /ɔ/, /o/, /ʊ/ or /u/, the mid front vowels are realised as the back rounded vowels [ɔ] and [o], depending on ATR category. For example, the verbal prefix marking 3SG is /-ɛ/ (or /e-/ under ATR harmony), as seen in (108a) and in (108b) (the latter being a Class 2 verb with the requisite stem-initial close front vowel). However, back rounded vowels appear when the prefixes are followed by back rounded vowels in the stem, as in (108c) and (108d).

(108)
a. ɛ́bák hit 3SG IPV [sk]
b. ɛìlík be cold 3SG [sl]
c. òlːúm punch 3SG [sm]
d. ɔ̀nɔ́k be hot 3SG [sn]

This assimilation process applies only to the mid front vowels and not the close front vowels or the open central vowel; for example, the 2SG prefix /ɪ-, i-/ is retained in (109a), and not realised as [ʊ-, u-], and the open central vowel in the 1SG prefix /a-/ is retained in (109b). If a morpheme containing a close-front vowel is inserted between the person-marking prefix and the stem, the assimilation does not occur; for example, forms as in (109c) are produced when there is a 3SG or 3PL subject as well as a 3SG or 3PL object, and show mid-vowel assimilation, but when a morpheme /-ɪ-, -i-/ is inserted to indicate agreement with a 1SG or 1PL object, the prefix vowel does not assimilate to the back vowel in the stem, as in (109d).

(109)
a. íwóló see 2SG [so]　　b. áwóló see 1SG [sp]
c. òwòló see 3SG [sq]　　d. eíwòlò see 3SG/1SG [sr]

The assimilation pattern can also be observed for mid vowels in various prepositions; for example, the preposition /dɛ̂/ 'at, on, in' is realised with a front vowel in (110a) but a back vowel in (110b), and the preposition /tɛ̀/ 'at, with, from' is realised with a front vowel in (110c) and a back vowel in (110d).

(110)
a. dɛ̂ máná at the farm [ss]　　b. dô xúnóm in the cave [st]
c. mɔ́ŋ tɛ̀ tárí? good evening [su]　　d. mɔ́ŋ tò móíté? good morning [sv]

However, there are a small number of exceptions to this pattern. The first is for the verb in (111a), which, though it contains a back vowel in the stem, does not show the usual assimilation process; the 3SG prefix is realised as a front vowel as shown in (111a), rather than as a back vowel. The stem-initial geminate palatal glide appears to have a similar blocking effect to the close-front vowels.[26] Similar examples can be found for verbs in which the onset is a cluster containing a palatal glide, as in (111c) compared to (111d).

(111)
a. jːò cry INF [sw]　　b. éjːò cry 3SG [sx]
c. ɾjóxó be dark INF [sy]　　d. èɾjók be dark 3SG [sz]

[26] There may also be some dialectal variation in whether or not assimilation processes apply for this verb; in Stirtz (2014, p. 46) the singular imperative form of this verb is given as /tɛjɔ/ and /tɛjɔj/ for the Dorik and Ngutira dialects respectively, but as /tɔjɔj/ for Lomiaha and Lohutok and /tɔjɛ/ for the Lolongo dialect. When checking with participants in the present study to see if [ójːò] is a valid pronunciation, all reported that it was not, but it was noted that this would be possible in the Lomiaha dialect area. Turner (2001, p. 46) transcribes /é̙jːò̙/for '3SG-cry'.

Interestingly, however, for the one verbal example so far with a singleton palatal glide as the initial segment of a stem with a back vowel, the assimilation does *not* appear to be blocked; the 3SG prefix is produced with a back vowel as shown in (112a), and this was consistent among the several speakers this was checked with. It is not clear whether this is specific to this word, or part of a more general pattern; one speaker suggested that the alternative, with [ɛ], would sound too similar to the 3SG form of another, Class 2 verb, shown in (112b). Other palatal consonants also do not have this blocking effect, for example as shown in (112c) for a verb with stem-initial /ɟ/.

(112) a. ɔ́jɔ́xà chew cud 3SG [ta] b. ɛ̀ìjɔ̀xá sit on 3SG [tb]
c. ɔ́ɟʊ́l push 3SG [tc]

The labial-velar glides also appear to trigger some differences in the pattern, but of the opposite sort; in verb stems beginning with a labial-velar glide followed by the open vowel /a/, the 3SG prefix /ɛ-/, /e-/ *will* be realised as a back rounded vowel, which would not usually occur before /a/. Consider, for example, (113a) and (113b), with the person-marking prefix followed by labial and velar consonants respectively. When the consonant is /w/ or /wː/ instead, the assimilation occurs; examples include (113c) and (113d).

(113) a. ɛ́bák hit 3SG [td] b. ɛ́káf lift 3SG [te]
c. ɔ̀wːànaî stay 3SG [tf] d. ɔ̀wáŋ be bright 3SG [tg]

If /w/ is the second segment in a consonant cluster, the assimilation process can also be observed, including with other non-back vowels following, as in (114a) and (114b), and also when the intervening consonant is not labial or velar, as in (114c). Therefore, it is the case that an onset containing a labial-velar glide triggers mid-vowel assimilation, and that this may occur with either a geminate /wː/ or singleton /w/ glide, indicating that the process is overall attributable to the rounding characteristic of segments.

(114) a. òmweî be sick 3SG [th] b. ókwɛ́dà take with tongs 3SG [ti]
c. ɔ́lwák help 3SG [tj]

3.4.3.3 Coarticulatory effects of glides

In addition to the changes in vowel category discussed above, there are some impressions of particular vowel types co-occurring with particular consonant types. Specifically, the close and mid front unrounded vowels and close and mid back rounded vowels preceding geminate glides tend to have a closer quality and be auditorily more like the [+ATR] vowels than the [-ATR] vowels, even in cases where a [-ATR] vowel quality would be predicted. For example, in the above example (113d), the 3SG prefix is a [-ATR] vowel, as expected given the [-ATR] /a/ in the stem, and is realised as a back vowel [ɔ], given the observed change from /ɛ/ to [ɔ] preceding stem-initial labial-velar glides. However, in an example such as (113c), the initial vowel will very often be realised as [+ATR] [o], despite the [-ATR] vowel in the stem. A pattern of this sort seems to be present when stem-initial glides are geminates, and in monomorphemic words, it may not be straightforward to decide on the best representation of a vowel preceding a geminate glide. It is worth noting that the similarity of the relevant [-ATR] vowel to a corresponding [+ATR] vowel appears to vary depending on the speech style – in natural or rapid speech, a [+ATR] quality is more likely, while in slow or emphatic speech, productions closer to a [-ATR] vowel can be heard.

Similar observations have been made for some other Eastern Nilotic languages; for example, Tucker and Mpaayei (1955, p. 240) observe that in Maasai, noun stems containing 'open' vowels /ɪ, ɛ, a, ɔ, ʊ/ will be preceded by gender-marking prefixes which also have 'open' vowels, /ɔ(l)-, ɛ(nk)-, while noun stems with 'close' vowels /i, e, o, u/ or 'strong' glides will be preceded by gender-marking prefixes with 'close' vowels, /o(l)-, e(nk)-/. Turner (2001) notes a similar tendency for /wː/ and /jː/ to occur with [+ATR] vowels in Lopit. For Otuho, some remarks of this sort are also made by Muratori (1938), and Coates (1985, p. 100-101) states similar observations more explicitly; she writes that occurrences of 'strong' /wː/ and /jː/ are "strongly influenced by the vowel harmony system", and that they are conditioned by surrounding ATR quality in that both /wː/ and /jː/ only occur between [+ATR] vowels. However, she also notes that 'weak' glides /w/ and /j/ are independent of the ATR system, and occur with both [+ATR] and [-ATR] vowels. If ATR quality is a conditioning factor on glide type, as Coates appears to suggest, it is not clear why the ‘weak’ glides can freely occur with [+ATR] vowels.

A more constrained proposal seems appropriate for Lopit; firstly, because the geminate glides are found freely, and often, between instances of /a/, which has been analysed as [-ATR] for morphophonological and phonetic reasons, and has no [+ATR] counterpart. Examples include (115a) and (115b).

(115) a. áwák want 1SG [tk] b. áwːár be alive 1SG [tl]

Geminate glides can also be followed by other [-ATR] vowels, for example in (116a) compared to the [+ATR] vowel in (116b). In these examples, the vowel following the geminate glide reflects the vowel quality in the stem of the verb from which each of these is derived. When [+ATR] suffixes are added to the derived nouns, the usual vowel harmony processes apply, giving rise to the forms shown in (116c) compared to (116d). It seems, then, that the ATR category of vowels preceded by geminate glides is not determined by the glide.

(116) a. xàjːɔ́xɔ̀k herders PL [tm] b. xájːòk mourners PL [tn]
c. xàjːóxònî herder SG [to] d. xájːônì mourner SG [tp]

If only vowels preceding the geminates are affected, the question is then whether this effect persists leftwards, as the ATR harmony does. There are few words available in which this can be checked, partly because geminate glides tend to occur towards the beginning of words, as they are often the first consonant in a stem, and partly because any preceding syllables containing /a/ block the spread of ATR harmony. However, some examples can be found which suggest that an effect on the quality of vowels preceding geminate glides does not apply to other preceding syllables. For example, the word for ‘buffalo SG’ is typically produced as in (117a); the vowel preceding the geminate labial-velar glide has a realisation closer to [+ATR] [o], while the vowel in the syllable preceding *that* is produced as [-ATR] [ɔ]. Similarly, the vowel in the persistive marker /lɔ-/[27] is produced with a closer quality preceding the geminate in (117b), but the person-marking prefix preceding that appears to retain the more open quality.

[27] This affix also has the forms /la-, lɛ-/, depending on person-marking.

(117) a. xɔ́sòwːàn buffalo SG [tq] b. ɔ́lôwːar be still alive 3SG [tr]

While this is certainly an area requiring closer investigation, current indications are that the [+ATR]-like quality of vowels preceding geminate glides does not appear to persevere further towards the left edge of the word, unlike the usual pattern in Lopit ATR harmony, and as such, the observed tendency is suggested to be one of localised coarticulation. Given that, as noted in 3.3.4, geminates /wː/ and /jː/ appear to have, impressionistically at least, a somewhat closer quality than singletons /w/ and /j/, perhaps indicating greater constriction, it would not be surprising if this were anticipated in preceding vowels. Some further discussion of this can be found in Chapter 5, where the phonetic characteristics of the glides, and some characteristics of the preceding vowels, are explored in more detail.

3.4.3.4 Front vowel coalescence

Where sequences of front vowels occur, particularly at morpheme boundaries, it is very common for them to be produced as a diphthong, and, in many cases, for coalescence to occur between the two vowel targets, resulting in a monophthongal articulation. This is not an obligatory process, and appears to be more or less frequent for different words, as produced by different speakers, but it is worth highlighting as it has potential implications for how lexical and morphosyntactic distinctions are maintained. This pattern can be seen, for example, for the noun in (118a), which has a singular form sometimes produced with a diphthong, as in (118c), but much more often produced with a monophthong, as in (118e). Similarly, for the noun in (118b), the addition of the singulative suffix /-i/ gives rise to either the singular form with a diphthong as in (118d), or with a monophthong as in (118f). It is worth noting that in these examples, and many others, the Falling tone which is often noted at morpheme boundaries involving number-marking suffixes is retained in the monophthongal realisations.

(118)
a. xìʔ breasts PL [ts] b. tàrùxàʔ vultures PL [tt]
c. xìnɛî breast SG [tu] d. tàrùxeî vulture SG [tv]
e. xìnê breast SG [tw] f. tàrùxê vulture SG [tx]

While the quality of the resulting monophthong appears to vary, and requires further exploration, it is often the case that sequences of both [-ATR] /ɛɪ/ (and /aɪ) and [+ATR] /ei/ result in a vowel with a quality most like that of [+ATR] /e/, at least in many word-final examples. Where this happens, the resulting vowel can then prompt other preceding vowels to harmonise to [+ATR], as outlined in (3.4.3.1). For example, the singular noun in (119a) is occasionally produced with a [-ATR] diphthong with the addition of the plural suffix /-ɪ/, as in (119b), but most often, it is produced with a final monophthong with a [+ATR] [e] quality, as in (119c), and the preceding vowel is also realised as [+ATR]. In examples such as this, the difference between inflected forms is in the vowel quality and tonal pattern, rather than an overt segmental morpheme.

(119) a. mɔ́ɲɛ́ father SG [ty] b. mɔ̀ɲɛɪ̂ fathers PL [tz]
c. mòɲê fathers PL [ua]

The same sort of coalescence is often observed when sequences of front vowels arise in verbs, for example when the 3SG prefix /ɛ-/ is added to Class 2 verbs, which, as noted elsewhere, always have a close vowel /i, ɪ/ as the initial segment of the stem. For example, the verbs shown in (120a) and (120b) may be produced with an initial diphthong in 3SG inflections, as shown in (120c) and (120d), or with an initial monophthong, as shown in (120e) and (120f). Often, the diphthongal form is more characteristic of very emphatic speech. For the verb in (120a), although the close front vowel of the stem is generally not produced in the 3SG forms, the verb class is still clear, because the mid-vowel assimilation process discussed in 3.4.3.2 does not take place; the prefix is realised as a front vowel rather than a back vowel, despite the back vowel /u/ being the only stem vowel realised in these examples. However, for the verb in (120b), for which no assimilation of the prefix is expected, the 3SG forms alone are not sufficient to indicate the verb class - the stem could be either Class 1 /tːab/ or Class 2 /ɪtːab/, and needs to be tested in other inflected forms.

(120) a. xìkùm punish INF [ub] b. xɪ̀tːàbà bribe INF [uc]
c. eìkùm punish 3SG [ud] d. ɛɪ̀tːàb bribe 3SG [ue]
e. èkùm punish 3SG [uf] f. ɛ̀tːàb bribe 3SG [ug]

While this pattern of vowel coalescence has been noted for a number of verbal examples, it is speculated that it may be somewhat more likely when the initial consonant of the stem is a geminate. Crosslinguistically, vowels preceding geminate consonants often occur with reduced duration values, and if this is the case in Lopit, it would not be surprising if this hinders attainment of the second target in a diphthong. The matter of vowel duration preceding geminates is investigated in Chapter 5, but further investigation of both vowel duration and vowel quality is required for the contexts discussed here.

3.5 Tone

3.5.1 Lexical contrasts

A number of tonal contrasts can be observed in Lopit. In the present data, there is evidence for three lexically contrastive tones: High and Low level tones, and a Falling contour tone, which, impressionistically, transitions from high to low pitch targets. The syllable is proposed as the tone-bearing unit, as has been similarly noted by Stirtz (2014b). Table 3.9 provides some examples of tonal contrasts in word-initial, word-medial and word-final positions. These contrasts can also occur on monosyllabic words in Lopit, though monosyllabic words are not common.

Tone appears to have a lower lexical than grammatical functional load in the language, as both Turner (2001) and Stirtz (2014b) have previously speculated, and as is commonly said of Nilo-Saharan languages. True minimal pairs are infrequent, but do occur, for example the noun in (121a) compared to the noun in (121b), and the verb in (121c) compared to verb in (121d).

(121)
a. lɔ́xɔ̀xɔ̀ʔ thief SG [uh]
b. lɔ̀xɔ́xɔ́ʔ shoulder SG [ui]
c. xíɲáŋ trick INF [uj]
d. xìɲàŋ buy INF [uk]

Minimal pairs are often members of different word classes, for example the singular noun in (122a) compared to the infinitive verb form in (122b), or the plural noun in (122c) compared to the imperative verb in (122d).

(122)
a. gɔ́rɔ́ large gourd SG [ul]
b. gɔ̀rɔ̀ strangle INF [um]
c. ìwːâʔ wings PL [un]
d. íwːàʔ care for baby IMP [uo]

More often, segmental differences provide additional cues to distinguish lexical items, as in the favourite example often provided by Lopit speakers, the comparison between (123a), (123b), and (123c), which concurrently illustrates differences in vowel quality and consonant gemination. Note that, as the examples throughout this chapter show, the three tones may occur freely with all [+ATR] and [-ATR] vowels.

(123)
a. xìtó child SG [up]
b. xìtɔ̂ scorpion SG [uq]
c. xìtːò bottom SG [ur]

It is worth providing some further detail regarding the proposed Falling tone, given that the literature on many African languages, including related Nilotic languages, frequently disprefers analyses involving contrastive contour tones. In many cases, alternative analyses are possible because Falling tones can be found to occur only as positional variants, or as a result of morphophonological processes. In Lopit, the Falling tone can occur in all word positions, as seen in Table 3.9, and examples of its occurrence include morphologically unmarked forms such as the nouns in (124a) and (124b), and the stems of verbs such as those shown in (124c) and (124d).

(124)
a. bɔ̂rɛ̀ stable SG [us]
b. xìmô nose SG [ut]
c. xìlːûʔ be warm INF [uu]
d. xìdôŋ appear INF [uv]

Table 3.9: *Examples of tonal contrasts in Lopit.*

Tone	Word-initial		Word-medial		Word-final	
High	márwák	animal horns PL [uw]	xìríŋò	meat SG [ux]	xìtó	child SG [uy]
Fall	mârwàk	old people PL [uz]	xìrîsò	walking stick PL [va]	xìtɔ̂	scorpion SG [vb]
Low	màrìŋ	fence SG [vc]	xìrìɟà	waterholes PL [vd]	xìtːò	bottom SG [ve]

However, the Falling tone does have a somewhat unbalanced distribution. It is not often found adjacent to High tones or other Falling tones, though examples can be found, for example among some inflected verb forms where it has grammatical significance. Among nouns, the Falling tone is particularly common word-finally, and for some words, its word-final occurrence may derive from elision and assimilation where number-marking suffixes are involved, for example as noted for the vowel sequences discussed in 3.4.3.4. This is likely a result of historical processes which have affected some words, and, partly due to the irregularity of number-marking morphology, is not predictable (and for some words, intra-speaker variation is noted). The Falling tone is also often found on plural suffixes such as /-a/ and /-o/, especially in cases where these are preceded by glide formation, as in the earlier examples (85d) and (78d). However, there are also many exceptions, so this is also not a predictable process.

While word-final occurrences of the Falling tone are often on open syllables, the Falling tone is not restricted by syllable type. An example of its occurrence in an open syllable is shown in (125a) (a grammatically unmarked plural) compared to (125b), with a sonorant coda in (125c) compared to (125d), and with an obstruent coda in (125e) compared to (125f). Lopit speakers often describe the Falling tone as 'heavy' or 'long'.

(125)
a. mɔ̀ŋâ magic stones PL [vf] b. mɔ̀ŋà whisper INF [vg]
c. xìdôŋ appear INF [vh] d. xìdòŋ stone INF [vi]
e. ceìtâʔ costume SG [vj] f. ceìtáʔ vomit INF [vk]

The observation of High, Falling and Low lexical tones in this study is somewhat different to other observations, though not markedly. In early work, Vossen (1982) proposes four tones for Lopit, consisting of High, Low, Mid, and High-Falling. Later work by Turner (2001) notes the presence of High and Low level tones plus a Falling contour tone, and more recent work by Stirtz (2014b) similarly reports High, Low and Falling tones, as well as a rare Rising tone. There are a number of possible reasons for these differences. While there is no clear evidence for a contrastive Mid tone in the present data for the Dorik dialect, it is certainly the case that there is a large range of phonetic realisations of tones from high to low pitch, and the difference between High and Low tones has at times been difficult for non-native ears to perceive. A closer look at Vossen's 157-item wordlist suggests that tones transcribed as Mid may actually be contextual variants of the High and Low tones. In addition, Turner (2001, p. 46-47) makes the general observation that Low and High tones towards the end of a phrase are lower than High and Low tones towards the beginning of a phrase, and furthermore that a noticeably higher tone occurs near the beginning of each phrase, and may be a particularly high realisation of the first High tone. This is discussed in more detail in Chapter 6.

However, it is of course possible that there are dialectal differences in Lopit tone inventories, given that the data in Vossen (1982) were based on a southern dialect, and the Dorik area is in the north. A lexical Rising tone has not been observed in Dorik Lopit, as it has been (rarely) by (Stirtz, 2014b) for the central Ngutira dialect; corresponding examples in Dorik are sequences of syllabic vowels with separate tones, e.g. Ngutira /hɔ̌yt/ compared to Dorik /xɔ̀ít/ in the present study, and may be better interpreted as notational rather than phonological differences. However, a marked word- or phrase-final rise does often appear on a large number of nouns (or noun phrases) grammatically marked for nominative case via other tone changes (see 3.5.2), and occasionally with other parts of speech, particularly in emphatic contexts. This intonation pattern is not obligatory, and may be related to focus-making, though it is feasible that it could function differently in different dialects.

3.5.2 Grammatical functions

Tone also has a number of grammatical functions in Lopit, some of which still require further exploration. The main grammatical function of tone among nouns is in case-marking. Lopit, like many Nilo-Saharan languages, has a marked-nominative system, and like many other Nilotic languages, the nominative case is marked using tone rather than segmental morphemes (Moodie, in progress). The case is indicated by a change in tonal pattern across the noun, and a range of tonal patterns can be observed to occur on nominative nouns, as shown in (126). When nouns are produced in isolation, the absolutive pattern is used. Analyses of the use of nominative and absolutive nouns in a range of constructions point towards the absolutive as the grammatically unmarked case (Moodie & Billington, 2015).[28]

[28]The term absolutive rather than accusative is used here following conventions in much of the literature on Nilo-Saharan morphosyntax (e.g. Dimmendaal, 2010).

(126)

a. ʈjàŋ animal (general term) SG [vl] | b. ʈjáŋ (general term) SG NOM [vm]
c. kɛ́r sheep SG [vn] | d. kɛ̀r sheep SG NOM [vo]
e. xábàɾàk cattle owners PL [vp] | f. xábáɾák cattle owners PL NOM [vq]
g. ìɾàsî brother SG [vr] | h. íɾàsí brother SG NOM [vs]
i. ìkúdòʔ squirrel SG [vt] | j. íkùdòʔ squirrel SG NOM [vu]
k. lóxìtːɔ̀k elder SG [vv] | l. lòxìtːɔ̀k elder SG NOM [vw]

As discussed further in Moodie and Billington (2015), the tonal alternations between absolutive and nominative nouns in Lopit are to some extent lexically specified, although some general tendencies can also be observed. From a sample of 253 disyllabic nouns, it can be seen that a pattern involving an initial high tone is quite common, occurring on 54% of nominative forms. Some examples are shown in (127).

(127)

a. mɔ̀ɾìŋ gazelle sp. SG [vx] | b. mɔ́ɾìŋ gazelle sp. SG NOM [vy]
c. fwàɾâ dancing area SG [vz] | d. fwáɾà dancing area SG NOM [wa]
e. xítɛ́ŋ cow SG [wb] | f. xítɛ̀ŋ cow SG NOM [wc]
g. xìtó child SG [wd] | h. xítò child SG NOM [we]

However, this appears to be mediated by a preference for making the tonal pattern across a nominative-marked noun the opposite to the tonal pattern in its absolutive form. Absolutive nouns with a L.L pattern are also often H.H in the nominative, as in (128a) compared to (128b), and those with a H.H pattern are also often L.L in the nominative, as in (128c) compared to (128d). In the sample, all L.F nouns and almost all L.H nouns have a H.L pattern in the nominative, as for (127d) and (127h), but nouns which already have an initial High (or Falling) tone in the absolutive may appear with various patterns, as shown in (128e) to (128j). In the former two cases, it is worth noting that similar case-marking tendencies are observed for nouns with either a High or Falling tone adjacent to a Low tone, indicating that the high initial target suggested earlier for the Falling tone may have a similar influence on the patterns as the level High tone.

(128)

a. xìdòŋ drum SG [wf] | b. xídóŋ drum SG NOM [wg]
c. tɔ́mɛ́ elephant SG [wh] | d. tɔ̀mɛ̀ elephant SG NOM [wi]
e. kúdòk round calabash SG [wj] | f. kùdók round calabash SG NOM [wk]
g. tʊ́tʊ̀r forest SG [wl] | h. tʊ̀tʊ̀r forest SG NOM [wm]
i. túxìʔ shield feathers PL [wn] | j. túxíʔ shield feathers PL NOM [wo]

In a small number of examples there is no change, and very occasionally there are different speaker preferences for the nominative tone pattern of a given word. Often, but not obligatorily, a noticeable final rise also occurs on the final syllable of a nominative noun, or noun phrase, as noted earlier. This has occasionally also been noted for absolutive nouns, or for verbs, particularly when speakers are being emphatic, and at present it is speculated that this may be more related to focus marking rather than case marking, though the two frequently go hand-in-hand.

In the verbal morphology, emerging evidence points towards tone being used in several ways, but its use depends on the morphological sub-class of the verb, which is influenced by the CV structure of the verb stem. For example, as discussed by Moodie (in press), the perfective aspect is marked on some Class 1 verbs (proposed Class 1a, with a C-final stem) with a segmental affix. For other verbs (proposed Class 1b, with a V-final stem), perfective aspect is indicated via tone changes, as shown in (129a) compared to (129b), and (129c) compared to (129d).

(129)
a. ádáxà eat 1SG IPFV [wp]
b. ádàxà eat 1SG [wq]
c. ɛ́jɛî die 1SG IPFV [wr]
d. ɛ̀jɛî die 1SG [ws]

The principles governing the tone patterns resulting from aspectual changes are actively being investigated (Moodie, in progress), and may also interact with occasional tone differences noted in different person inflections of the same verb, and with the tone changes that often co-occur with the addition of other segmental morphemes. For example, different tone patterns are sometimes observed for first compared to third person inflections of a given verb, as for the 1SG verb form in (130a) compared to the 3SG verb form in (130b). However, possible tone differences for person-marking appear to have relevance only for some verbs, in some inflections, but not others. The 1SG verb form in (130c) and the 3SG verb form in (130d) have the same tonal pattern, but when the ventive suffix is added, their tonal patterns differ, as in (130c) compared to (130d). These matters, and many others affecting tonal patterns, remain to be teased apart.

(130)
a. aíbɔ̀ reject 1SG [wt]
b. ɛìbɔ̀ reject 3SG [wu]
c. áxój:à forage 1SG [wv]
d. óxój:à forage 3SG [ww]
e. áxój:aú forage 1SG VEN [wx]
f. òxòj:aù forage 3SG VEN [wy]

For other inflected forms, the tone patterns are more predictable. For imperative verbs, it is very common for the tone pattern to be, depending on the length of the word, H.L, H.H.L, or H.H.L.L, regardless of the verb class (though there are exceptions, as for the example shown in Figure 3.8). Various examples can be seen elsewhere in this chapter, for example the Class 1 verbs in Table 3.11, as well as for Class 2 verbs in (122d) and (103a) (though note also the tone difference for the imperative with a ventive suffix in (103b). Imperative forms of Class 2 verbs take an /ɪ-/ prefix rather than the /tɛ-/ prefix used for Class 1 verbs, and given that 2SG is also marked with a /ɪ-/ prefix, this means that tone patterns may be the only difference between some 2SG and IMP forms of Class 2 verbs, for example as in (131a) compared to (131b).

(131) a. ífwó cook 2SG [wz] b. ífwò cook IMP [xa]

At this stage it is not yet clear whether verb stems are specified for tone, and if so, to what extent this also interacts with grammatical uses of tone in the verbal morphology. As the examples in this section show, there are various interacting complexities associated with the phonological and morphological functions of tone in Lopit, providing analytical and descriptive challenges which are very typical of research on Nilo-Saharan languages. There is clearly a great deal of scope to improve the understanding of these matters as research on Lopit continues, and a more detailed understanding of morpho-syntactic tonal processes will in turn allow greater scope to investigate factors affecting the phonetic realisation of tone, and to explore patterns of intonation beyond the word.

3.6 Phonotactics

3.6.1 Word structure

In the present data, words of up to six syllables are attested, but words of 2–3 syllables are more usual. In the lexical database compiled in the course of this work, words with CV.CV and CV.CV.CV patterns are most common. Different patterns may emerge when looking across transcribed texts, given that inflected verb forms often have an initial V syllable (and most verb forms in the lexical database are consonant-initial infinitival forms). Noun stems appear to most often be disyllabic, though trisyllabic stems are also common. Verb stems also appear to often be disyllabic or trisyllabic, but various monosyllabic stems also feature, and for a number of verbs, identification of the stem is the subject of ongoing work.

As briefly discussed in 1.4.3, various inflectional and derivational patterns may be applied to nouns and verbs. In the segmental morphology, most bound morphemes are monosyllabic. For nouns, segmental morphemes are used for example in number-marking (mostly suffixes, some prefixes) and in deriving nouns from verbs, or from other nouns (circumfixes, prefixes, and suffixes). For verbs, there is a large range of inflectional and derivational possibilities (mostly prefixes, some suffixes), and greater potential for these to co-occur. Detailed discussion of Lopit inflectional and derivational morphology is beyond the scope of this work, but can be found in Moodie (2012, 2016, in press, in progress), whose concurrent work on the Dorik dialect has informed this study, as well as in work by Ladu, Nartisio, Bong, Odingo and Gilbert (2014b) across different Lopit dialects. Various examples of morphological patterns have, however, been noted throughout this chapter, for example in 3.4.3.

3.6.2 Syllable structure

The examples presented throughout show that various syllable types are possible in Lopit, though with some restrictions as to how they may co-occur. The maximal syllable structure is shown below; C indicates a consonant, V a vowel, and G a glide.

(C)(G)V(C)

The six attested syllable types are shown in Table 3.10 with corresponding examples of monosyllabic words, except in the case of VC syllables, which only occur in a small number of longer words. Examples with geminate onsets are included. Very few monosyllabic words have V syllables; in addition to the preposition shown, the only other examples include /ɛ/ 'yes' and other interjections (in which the vowel is typically produced quite long). However, some high-frequency words are often produced as V syllables in their reduced form, such as the production of /aɾa/ 'be' as [a]. Monosyllabic words are not common in Lopit; most examples of monosyllabic words are nouns, and most monosyllabic nouns are CVC syllables.

Table 3.10: *Monosyllabic words showing Lopit syllable types.*

Syllable type	Monosyllabic example	
V	à	to [xb]
VC	-	
CV	cà	dance SG [xc]
C:V	jːò	cry INF [xd]
CVC	ɲát	swamp SG [xe]
C:VC	wːòr	small hole SG [xf]
CGV	njà	that F [xg]
CGVC	kwàn	body SG [xh]

The syllable types shown in Table 3.10 include onset clusters with glides, in an analysis that differs slightly from some proposals in previous work. As noted in 3.3.4, Turner (2001, p. 51-56) transcribes similar patterns of segment distribution in his Lopit data, but leans towards an analysis interpreting the glides as vocalic rather than consonantal when they follow other consonants, for reasons more to do with descriptive simplicity than any differences in the data collected. Stirtz (2014b, p. 13-16) proposes an analysis allowing complex onsets, as in the current work, but also suggests that glides may occur as the first segment in complex codas, which, as discussed in 3.4.2, is motivated by a dispreference for positing contrastive diphthongs, and therefore is also more suggestive of differences in analytical approaches than differences in the lexical data collected.

Further examples of these different syllable types are shown in Table 3.11. The words shown are all disyllabic verb forms, and the different syllable types are exemplified in the second syllable, which is the verb stem in each case. In various sections of the preceding discussion, it has been suggested that the initial consonant slot of a verb stem is a particularly salient position for consonantal contrasts. The occurrence of clusters in this position similarly points towards their significance in the Lopit phonological system. Examples are shown for Class 1 verbs, and for CV and CVC syllables, examples with a geminate onset are also shown. The same four primary syllable types are also observed among nouns of various word lengths, as can be seen throughout this chapter, but the interaction between syllable structure and other aspects of Lopit verbal morphology is a topic particularly worthy of further research.[29]

Apart from the glottal stop, all consonants, including geminates, can occur as syllable onsets, and apart from /dː/ and /ɾ/, all of these may occur in word-initial position (though very rarely for /nː/). As discussed in 3.3, not all consonants may occur as syllable codas; among the obstruents, /b, f, t, d, ɟ, s, k, ʔ/ may occur as coda consonants, but very infrequently in the case of the voiced stops. Sonorants /m, n, ŋ, ɲ, r, l/ are also found in coda position. Closed syllables are found word-finally only, apart from in a small number of examples discussed below. This differs from the analysis proposed by Stirtz (2014b) who, as noted in 3.3, found more limited evidence for word-initial geminates and interprets medial geminates as sequences of identical consonants across a syllable boundary, as an alternative to proposing geminate consonants as contrastive.[30]

3.6.3 Consonant sequences

As noted above, onset clusters with a palatal or labial-velar glide as the second segment are often found. Some discussion and examples featured earlier in 3.3.4. In the data collected so far, the labial-velar glide is found after /p, b, f, t, d, c, k, g, m, n, ɲ, ŋ, r, ɾ, l/, and the palatal glide after /f, t, d, k, m, n, ŋ, r, ɾ, l/. Apart from sequences of these segments followed by /w/ or /j/ in onsets, data for the present study indicate that consonant

[29]For example, while not discussed here, there is emerging evidence that there are inflectional differences between Class 1 verbs with CVC roots, and Class 1 verbs with roots ending in open syllables (Moodie, in press, in progress).

[30]Note, however, that the status of geminates as contrastive does not preclude an analysis which allows geminates in different word positions to have different syllabic affiliations. The examples with geminates in Table 3.11 represent them as onsets, because these examples are intended to illustrate the shape of the stem, but analysis of medial geminates as coda-onset sequences may be tenable. It is worth noting that in very careful, hyperarticulated speech intended to emphasise the correct pronunciation of a word, Lopit speakers may sometimes pause before beginning to produce a medial geminate, but there are no recorded examples of this type of speech in which a medial geminate is realised as a coda and onset separated by a pause, suggesting at least a close affiliation between a geminate consonant and the vowel which follows.

Table 3.11: *Examples of main syllable types in Lopit, shown in verb stems (second syllable of each disyllabic word).*

Syllable type		Example
CV	ɛ̀.cà	dance 3SG [xi]
	tɛ́.cà	dance IMP [xj]
C:V	é.jːò	cry 3SG [xk]
	té.jːò	cry IMP [xl]
CVC	ɔ́.ŋɔ́t	cut 3SG IPV [xm]
	tɔ́.ŋɔ̀t	cut IMP IPV [xn]
C:VC	ò.lːúm	punch 3SG IPV [xo]
	tó.lːùm	punch IMP IPV [xp]
CGV	ó.kwò	splash 3SG [xq]
	tó.kwò	splash IMP [xr]
CGVC	ɔ́.lwák	help 3SG IPV [xs]
	tɔ́.lwàk	help IMP IPV [xt]

sequences are dispreferred. Turner (2001) suggests a small number of ideophones containing initial /tr/ sequences, for example as in (132a), which do not appear to be used or known by the present participants with the exception of the example in (132b).

(132) a. <trùbèŋ> sudden meeting [DT] [xu] b. trʊ̀bɛ̀lɛ̀k surprise interruption [xv]

Loanwords provide some evidence that other potential consonant sequences are typically adapted to CV syllables. In (133a), vowel epenthesis breaks up the initial cluster of the English source word /skuːl/, and in (133b), vowel epenthesis breaks up a cluster and the initial vowel has also been deleted from the Latin form /ekːleːsia/. Epenthesis again resolves the potential cluster in (133c), a word ultimately of Arabic origin but suggested (by a participant) to have been borrowed from Ottoman Turkish /leʃker/. Occasionally, consonant sequences occur across syllable boundaries in borrowings, as in (133d).

(133) a. sʊ́kʊ̀l school SG [English] b. kèlèsíjà church SG [Latin]
c. lɔ́sɛ̀ŋɛ̀r army PL [Ottoman Turkish] d. dìktɔ̀r doctor SG [English]

Stirtz (2014b) proposes some examples with consonant sequences (in addition to the proposed sequences which form geminates) which are not found in the present data; for example, he reports the form in (134a) as used by the Dorik contributor for the word 'sand', but the form used by the Dorik participants in the present study, shown in (134b), has an onset cluster with a velar nasal and palatal glide rather than a velar nasal and palatal nasal sequence.

(134) a. <ciŋɲati> sand [Dorik - TS] [xw] b. sìŋjátí sand [xx]

In the present data, most examples of consonant sequences across syllable boundaries are words in which the stem is reduplicated. Turner (2001, p. 50) notes one example of this sort, shown in (135a), and others found in the current study are shown in (135b) to (135f). At least some of these are suggested, by the participants, to be ideophonic, connoting particular types of sound or movement. These examples function as single words, and there is limited evidence that the reduplicated portion can also stand alone, except in the case of (135c) which has a variant /lɔ̀kítʉ̀k/.

(135)
a. <ɲítɲít> sharp pain [DT] [xy] b. pìk-pík motorcycle SG [xz]
c. lɔ̀kítʉ̀k-kítʉ̀k earthquake SG [ya] d. kámák-kàmàk jawbones PL [yb]
e. lɔ́fɛ̀ɾɛ̀ŋ-fɛ̀ɾɛ̀ŋ swift sp. SG [yc] f. lɔ̀kídɛ̀k-kídɛ̀k pied wagtail sp. SG [yd]

However, these examples are all nouns; while reduplication also occurs in verbs, if there is a CVC stem, only the CV portion is reduplicated, for example as shown in (136a) and (136b).

(136) a. aìgígíló think 1SG REDUP [ye] b. aídúdúxú gather 1SG REDUP [yf]

Table 3.12: *Examples of minor syllable types in Lopit, shown in polysyllabic words of various classes.*

Syllable type	Example		Example	
V	à.í.ná	today [yg]	ì.tà.ú.xíʔ	ostrich PL [yh]
	fà.ì.tôʔ	ebony trees PL [yi]	xò.í.toì	bone SG [yj]
	ɛ̀.ŋà.í.nó	go 3SG [yk]	lò.î.tî	sugarcane SG [yl]
VC	í.tà.ʊ̀k	ostrich SG [ym]		
	xò.ít	bones PL [yn]		
	lò.ît	sugarcane PL [yo]		

3.6.4 Vowel sequences

While V syllables are in fact reasonably common, they most often occur word-initially, typically as a person-marking prefix on a verb, as the examples in Table 3.11 show, or in the initial close-front vowel often found on nouns, as noted in 3.4.1. In these cases, they are followed by a CV syllable. However, vowel sequences are noted in a number of examples in which a V or VC syllable follows a CV syllable. In the six examples of word-medial V syllables listed in Table 3.11, and several others like these, the vowels are clearly distinct syllable nuclei, and consistently produced in this way by various speakers. These productions are qualitatively different to both examples with vowels separated by an intervening (phonetic or phonemic) glide, and to diphthongs. The three monomorphemic words with final VC syllables are the only examples of VC syllables noted, but again, the speakers are consistent in their realisations of these as distinct syllable nuclei (and vowel sequences also appear in the number-marked forms shown in the same table)[31]. In these various examples of vowel sequences, the adjacent vowels may have either the same or different tones.

Some corresponding examples noted by Stirtz (2014b) show slight differences, but also indicate varying productions across dialects. For example, as noted earlier in 3.5, the form used for 'bones PL' by the Ngutira participant in the study is represented as in (137a), with a Rising tone (and the Dorik form is shown with the same segments, but without tones marked), while the Lomiaha form, shown in (137b), instead has two vowels separated by a fricative. The form used by the Dorik participant for 'ostrich SG', shown in (137c), has a medial labial-velar glide instead of a V.V sequence, while the Ngutira form in (137d), which is segmentally the same as for the remaining dialects, is a disyllabic rather than trisyllabic word. Further work will be required to identify if there is any historical connection between these, and other, pronunciation differences across dialects. Regarding the present data, it may be that V.V sequences have arisen from the elision of a medial consonant, as has been noted previously as an optional variant for specific words, for example those in (44). It may also be that some dialects have moved

[31] The word for 'bone SG' may also be produced as /xò.í.teì/ or /xò.í.tè/ YP; the form in Table 3.11 is more characteristic of careful speech.

towards monophthongs or diphthongs in place of original V.V sequences; for example, cognates for the word 'bone/s' across various Eastern Nilotic languages indicate that a V.V sequence is common Vossen (1982, pp. 124–127). Regardless of their origin, vowel sequences involving medial V or final VC syllables are marginal in the current data for Dorik Lopit.

(137)
a. <hɔ̆jt> bones PL [Ngutira - TS] [yq]
b. <hɔhit> bones PL [Lomiaha -TS] [yr]
c. <itawuk> ostrich SG [Dorik - TS] [ys]
d. <ítàk> ostrich SG [Ngutira - TS] [yt]

3.7 Discussion and Chapter Summary

Based on analyses of segmental and tonal patterns in extensive data for the Dorik variety of Lopit, this chapter has presented a number of proposals regarding the inventory of consonants, the vowel system, tonal contrasts, phonotactic patterns and key phonological processes. These proposals amount to a description of the sound system of Lopit that has much in common with what is observed for other non-Bari Eastern Nilotic languages, with reference to the overview in Chapter 2; there are nasals and voiced and voiceless stops at four supralaryngeal places of articulation, a small number of fricatives, several sonorants, nine monophthongs with an ATR contrast, and High and Low level tones plus a Falling contour tone.

Some of the observations presented here also raise further questions, for example the possibility of historical lenition processes contributing to the current status and distribution of fricatives and the glottal stop, the principles governing patterns of grammatical tone and their interactions with intonational structures, possible dialectal differences in the use of different segments and tones, and the role of lexical frequency and individual speaker differences in some of the observed variation. The analyses presented here significantly develop the understanding of Lopit phonology, and, joining other early and recent observations on aspects of the sound system, contribute to a more comprehensive descriptive base from which the investigation of some of these matters can proceed.

However, some additional questions arise regarding the phonetic nature of some of the consonants, vowels and tones which are here suggested to be phonemic, and which have bearing on their status in the sound system of Lopit. For example, the phonological feature which has been suggested to distinguish the two proposed classes of vowels is ‘Advanced Tongue Root’, which, as discussed in 2.3, is widely attested in African languages, but which has been correlated with a range of acoustic and articulatory characteristics. The phonetic characteristics distinguishing the two classes of vowels, and more generally distinguishing the nine proposed monophthongs from one another, therefore require closer examination. This is particularly the case given that in existing observations of Lopit phonology, as noted in 3.4.1, there is some uncertainty about the possibility of a [+ATR] counterpart to /a/, and an alternative proposal for a five-vowel system with no ATR contrast. The need for closer examination of the phonetic nature of the vowel contrasts proposed for Lopit is taken up in the next chapter, Chapter 4.

Length contrasts have been proposed for several consonants, including glides at the same place of articulation, discussed in 3.3.4. As noted in 2.2.4, glide length contrasts are typologically uncommon, and there are suggestions that this may be because their highly sonorous nature potentially makes it difficult to reliably perceive, and perhaps produce, differences based on constriction duration. Given this, a targeted investigation of the putative singleton and geminate glides in Lopit is required to verify their status in the language. There is also a wider need for detailed language-specific information on the nature of singleton and geminate glides, given that very little phonetic data has been available to inform crosslinguistic generalisations regarding these speech sounds. While previous authors on Lopit have similarly noted the possibility of such a contrast, and contrastive ‘long’ or ‘strong’ glides are described for other related languages, some of these descriptions, as well as the impressions recorded in the present work, hint at the possibility of articulatory differences for the geminate compared to the singleton glides. This suggests that not only do the durational characteristics of Lopit need to be investigated, but other phonetic characteristics as well. This is taken up in Chapter 5.

Proposals put forward in 3.5 for the tone system include High and Low level tones and a Falling contour tone. A tone inventory of this sort is typical of Eastern Nilotic languages, as discussed in 2.4, though the status of the Falling tone is not always clear across languages, and there have been virtually no quantitative investigations of tone systems in the language family. The proposals for Lopit differ in only minor ways from suggestions made in other work on the language, but given that these include, for example, an additional Mid tone, there is need to assess the phonetic evidence for the tone categories proposed here. There is also a strong argument to be made for testing the tonal contrasts in the earlier stages of linguistic description, given that tone has been shown to have a significant role in Lopit morphosyntax and ongoing analysis of its functions depends on a clear conceptualisation of the relevant categories. At the same time, the grammatical significance of tone means that phonetic investigations need to be informed by descriptions of its various functions, which imposes some limitations on what can be tested when the linguistic analyses are still emerging. A first look at the phonetic characteristics of Lopit tones is presented in Chapter 6.

Chapter 4

Acoustic and Articulatory Characteristics of Lopit Monophthongs

4.1 Introduction

In the previous chapter, Chapter 3, an outline of Lopit phonology was put forward, based on analyses of lexical and morphosyntactic data collected during this project (with a focus on the Dorik variety of the language). A series of proposals regarding the Lopit consonant, vowel and tone inventory were described, including a proposal for the contrastive monophthongs /i, ɪ, e, ɛ, a, o, ɔ, u, ʊ/ for the vowel system, potentially with an 'Advanced Tongue Root' (ATR) contrast distinguishing selected pairs of vowels. In this chapter, I explore the Lopit vowel system, and any evidence for an ATR contrast, in more detail, with reference to phonetic data collected in the course of two production experiments, one based on audio-recorded speech data and the other based on video-recorded data collected using ultrasound tongue imaging. As discussed in Chapter 2, in existing observations for Lopit and various other Nilotic languages there are remaining uncertainties and inconsistencies relating to vowel systems. In some cases there are different analyses regarding the number of contrastive monophthongs, and different views regarding the presence of ATR as a phonological feature, and its phonetic correlates. The phonetic implementation of ATR distinctions has also been a question of wider typological interest for many years. The analyses presented in this chapter relate to RQ2, "What are the acoustic correlates of vowel contrasts found in Lopit?" as well as RQ3, "What sorts of articulatory mechanisms are involved in producing Lopit vowel contrasts?". Selected findings pertaining to these questions have also been discussed in Billington (2014).

The phonological evidence presented in Chapter 2 points towards a contrast between 9 monophthongs (3.4.1), as well as to a vowel harmony process involving alternations between certain vowels (3.4.3.1). These patterns indicate that vowels fall into two classes; one comprising /i, e, o, u/ and another comprising /ɪ, ɛ, ɔ, ʊ, a/. Vowels in the former were impressionistically noted to have a closer quality than vowels in the latter. Given similarities between these findings and patterns described for closely-related languages, the label [+ATR] was adopted for the former, and [-ATR] for the latter. Both in terms of the number of vowels, and the presence or absence of an ATR contrast, there are some differences between this and other proposals for Lopit phonology, as noted in 2.3.2 and discussed further below. Assessing the phonetic evidence for proposed vowel contrasts is therefore a primary concern of this chapter, and ascertaining whether vowel contrasts involve distinctions drawing on known acoustic and articulatory correlates of ATR is a crucial part of this. Of specific interest is the evidence for acoustic and articulatory differences between /i, ɪ/, /e, ɛ/, /o, ɔ/ and /u, ʊ/. These pairs of [+ATR] and [-ATR] specified vowels of similar height, backness and rounding are henceforth called harmonic pairs given their relevance to vowel harmony processes. In addition, the question of whether there is a [+ATR] counterpart to [-ATR] /a/ is addressed, a matter of some uncertainty in other work on languages in the Lotuxo family. In existing work on other languages with putative ATR contrasts, the pairs /ɪ/, /e/ and /ʊ/, /o/ (in which the first in each pair is a [-ATR] close vowel and the second a [+ATR] close-mid vowel) are often noted to be auditorily very similar, with potential implications for sound change processes, so the evidence for differences between these is also given specific attention. These pairs are henceforth called the close/mid pairs to distinguish them from the harmonic pairs. As mentioned in 2.3.1 and addressed in more detail in 4.2.3 and 4.2.4, the acoustic and articulatory correlates of the feature ATR have been subject to much debate, and have only been investigated for a very small number of the many languages of Africa and elsewhere suggested to have such a contrast. Though some general trends have emerged, there are indications that the phonetic implementation of ATR may be more variable than early work supposed, particularly among Nilo-Saharan compared to Niger-Congo languages. Acoustic measures of interest for the present analyses include the frequencies of the first three formants, duration, and spectral emphasis. These are complemented by articulatory investigations of the lingual gesture used for vowels, based on data collected using ultrasound tongue imaging.

This chapter is structured in the following way: 4.2 builds on the observations of previous chapters to provide a crosslinguistic overview of ATR contrasts and their phonetic correlates, including the contrasts proposed for Lopit and related languages, from which the hypotheses presented in 4.3 emerge. Methodological details pertaining to the acoustic investigations are given in 4.4, and the results for these investigations are then presented, according to each measure of interest, in 4.5. The methodological details for the articulatory analyses are then provided in 4.6, and findings for the lingual gestures used in the production of Lopit vowels are discussed in 4.7. Extended discussion of the findings, and their relevance to the given hypotheses, is contained in 4.8.

4.2 Background

4.2.1 ATR phonology and typology

Many languages of Africa, as well as some elsewhere, are described as having vowel systems with a contrast on the basis of the phonological feature ‘Advanced Tongue Root’ (ATR), which was briefly introduced in 2.3.1. These are particularly common among languages of the Niger-Congo and Nilo-Saharan phyla (Casali, 2003). The feature ATR is held to distinguish vowels of a similar height, backness and rounding, and for languages with such a contrast, vowels are typically divided into two sets: those with [+ATR], and those with [-ATR] (Ladefoged, 1964; Stewart, 1967; Lindau et al., 1972; Ladefoged & Maddieson, 1996b; Casali, 2008). The labels [+ATR] and [-ATR] (also [ATR] and [RTR], among other options) reflect the assumption that “at least to a first approximation, the relevant phonetic distinction is that [+ATR] vowels are articulated with the root of the tongue in a more advanced position in the vocal tract, and [-ATR] vowels with the tongue root in a less advanced position” (Casali, 2008, p. 496). As a phonological feature, ATR has not been without controversy; the range of possible phonetic correlates which have been the subject of both speculation and experimentation has meant that some researchers prefer to view ATR as an abstract phonological feature, with no direct mapping between the feature and the actual position of the tongue root (e.g. Hyman, 1988b), while others argue, with reference to instrumental evidence, that a level of direct mapping of specific phonetic gestures onto ATR phonological patterns is possible (Hudu, Miller & Pulleyblank, 2009). Some aspects of this, particularly the crosslinguistic validity of proposed phonetic-phonological mappings, are addressed in later sections, alongside discussion of the articulatory (4.2.3) and acoustic (4.2.4) findings in existing work.

The most straightforward cases of ATR contrast, according to Casali (2008, p. 499), occur in languages which have a symmetric system of ten contrastive vowels, consisting of five [+ATR] vowels and five [-ATR] vowels. Typically, for a 10-vowel system, the [+ATR] vowels might be represented as /i, e, ə, o, u/, and [-ATR] vowels represented as /ɪ, ɛ, a, ɔ, ʊ/, or alternatively as /i̘, e̘, a̘, o̘, u̘/ compared to /i, e, a, o, u/.[1] There are then five pairs of vowels distinguished by their [ATR] specification, for example as posited for a number of Niger-Congo languages, such as Degema (Fulop, 1996; Kari, 2007), Ikposo (Anderson, 2003), and Gusilaay (Yashina, 2011), as well as many Nilo-Saharan languages, such as Bari (B. L. Hall & Yokwe, 1981), Bongo (Kilpatrick, 1985) and Shilluk (Remijsen et al., 2011). 10-vowel ATR systems have also been proposed for some Afro-Asiatic languages, such as Somali (Saeed, 1999). While 10-vowel ATR systems are the most straightforward, or symmetrical, 9-vowel systems are more common; in these, the open vowel /a/ (usually specified as [-ATR]), has no counterpart of the opposite ATR specification (Clements & Rialland, 2008; Casali, 2008). Numerous examples of these can be observed across languages of sub-Saharan Africa, such as Niger-Congo Akan (Hess, 1987), Foodo (Anderson, 2006), and Chumburung (Snider, 1989), and Nilo-Saharan Luo (Jacobson, 1978; Swenson, 2015), Maa (Guion et al., 2004), and Didinga (de Jong, 2004). Seven-vowel systems, with an ATR contrast only among the mid or close vowels, also occur often (Starwalt, 2008;

[1]Researchers differ with regard to their interpretation of the vowel height differences implied by the IPA symbols chosen for [-ATR] vowels in the first example; some hold these to be part of the contrast (e.g. Clements & Rialland, 2008), while others prefer to avoid the implication by instead using the advancement diacritic for [+ATR] vowels).

Clements & Rialland, 2008; Casali, 2003, 2008).

Pairs of [+/-ATR] vowels are important in the harmony processes typically attested alongside ATR contrasts in African languages; where a vowel is paired with a similar vowel of the opposite ATR specification, this vowel can be considered its harmonic counterpart (Casali, 2003, 2008). Vowel harmony requires that vowels in a given domain, generally the phonological word, share particular features, or groups of features (Rose & Walker, 2011). In general, for languages with ATR harmony, the tendency is for all vowels in a word to agree in terms of their [+ATR] or [-ATR] specification. In root morphemes, vowels specified for one of these properties are not expected to co-occur with vowels specified for the other. The addition of affixes with an opposing ATR specification compels some of the vowels in the word to change ATR specification to maintain (to the extent possible) the preference for a shared ATR feature across the word. Very often, [+ATR] is the dominant feature, prompting [-ATR] vowels to change to [+ATR] (Clements, 2000; Clements & Rialland, 2008; Casali, 2003, 2008). Such processes may not apply to all vowels in an inventory; an obvious example is cases in which the open vowel /a/ lacks a [+/-ATR] counterpart, and may combine with vowels of both series and, frequently, interrupt the spread of ATR harmony (Casali, 2008, pp. 527–532). While there are some clear crosslinguistic tendencies in the implementation of ATR harmony processes, these are mediated by various language-specific factors, for example in how historical changes resulting in disharmony are handled within the system (Dimmendaal, 2002), or correlations between particular types of vowel inventories and a preference for [-ATR], rather than [+ATR], as the dominant feature (Casali, 2003, 2008, 2014, 2016).

Though early work regards ATR as a characteristically African phenomenon (Stewart, 1967), distinctions on the basis of tongue root position and associated gestures have also been proposed for vowel systems in languages outside Africa, on the basis of perceived contrasts as well as harmony processes. These include Mon-Khmer languages of southeast Asia, such as Pacoh and various others (Watson, 1996; Gregerson, 1976), as well as Tibeto-Burman languages such as Yi and Bai (Edmondson, 2009). Examples are also found among the Tungusic and Mongolic languages of northeast Asia, such as Even (Aralova, Grawunder & Winter, 2011), Manchu (Dresher & Zhang, 2005), Buriat (H. Kang

& Ko, 2012) and Khalka Mongolian (Ko, 2012). These contrasts are also often described as register differences, and in some languages of these regions they interact with differences in pitch and other properties. Descriptions of some languages in the Americas also draw on tongue root characteristics, such as those for Nez Perce (B. L. Hall & Hall, 1980), a Sahaptian language of North America, and for Karajá, a Macro-Jê language of South America (Fulop & Warren, 2015). A number of analyses of Romance languages also propose tongue root differences between vowels in the vowel inventory, for example for Canadian French (Poliquin, 2006), Italian (Calabrese, 2000), and Spanish (Hualde, 1989). Some additional examples from other language groups are noted by Casali (2008), who also observes that, at least superficially, some of the non-African ATR systems exhibit significant differences from typical examples among African languages. For example, as pointed out by Clements and Rialland (2008), impressions are that it is often retraction of the tongue, rather than advancement, which is dominant in terms of harmony processes for non-African languages. As for many African languages, invocations of tongue root contrasts for non-African languages are often speculative, due to the challenges of instrumental observation and to prejudices of articulatory attribution. +ATR/-ATR descriptors have also been applied to vowel contrasts traditionally described as Tense/Lax, for example in English, German, and other Germanic languages, but acoustic and articulatory investigations indicate that despite phonetic similarities, there are observable differences in how Germanic vowel contrasts are implemented compared to those in canonical Niger-Congo ATR systems (e.g discussion in Ladefoged & Maddieson, 1996b), though the picture may be more complicated compared to the limited phonetic data available for Nilo-Saharan ATR systems (Lindau et al., 1972). Furthermore, Germanic languages do not utilise the feature as the basis of a vowel harmony system. These matters are discussed further in 4.2.3 and 4.2.4.

4.2.2 Vowel contrasts and processes proposed for Lopit

As discussed in 2.3, 9- to 10-vowel ATR systems are common in Eastern Nilotic languages. 10 vowels is most typical of those in the Bari family, and 9 vowels more common elsewhere in Eastern Nilotic, though the possibility of a tenth vowel, as a [+ATR] counterpart to /a/, is suggested for some languages. This is the case in proposals for Otuho and closely-related varieties, including Lopit; Vossen (1982) suggests two sets of five vowels, distinguished by ATR, but adds that [+/-ATR] open vowels cannot be distinguished phonetically, and represents both as /a/. In early work on Otuho, Muratori (1938, p. 3) indicates that there may be a perceptible difference, as does Coates (1985) in later work, with the caveat that this “is not considered important by native speakers” (1985, p. 96). For Lopit, remarks by Vossen (1982), based on data collected with a speaker from the central dialect area, are followed by later work by Turner (2001), who provides a more detailed exploration of Lopit phonology based primarily on data collected with speakers from the southern and central areas. Like Vossen (1982), Turner (2001, pp. 40–41) lists two sets of five vowels, including [+ATR] /i̘, e̘, a, o̘, u̘/ and [-ATR] /i, e, a, o, u/, with /a/ appearing in both categories. However, he notes further that Lopit speakers do not distinguish between [+ATR] and [-ATR] /a/, and observe only one phoneme, adding that this matches his own impressionistic observations, and that if there are indeed two open vowels, they must be phonetically very similar. These proposals of 9 (or possibly 10) monophthongs for Lopit contrast with those put forward by Stirtz (2014b), who lists only five phonemic vowels /i, ɛ, a, ɔ, u/, and states that there was no evidence of an ATR distinction[2] for the five Lopit speakers who participated in the study, representing the Dorik, Ngutira, Lomiaha, Lohutok and Lolongo dialect areas (the northernmost, Ngabori, was not represented). In the wider study which the present quantitative investigation is part of, the findings have much in common with, and expand on, observations by Vossen (1982) and Turner (2001). As described in detail in 3.4, impressions based on data for the Dorik dialect are of 9 contrastive monophthongs, which, drawing on various types of evidence, can be divided into two sets: /i, e, o, u/, for which the label [+ATR] has been used, and /ɪ, ɛ, ɔ, ʊ, a/, labelled [-ATR]. As noted, the label ‘Advanced Tongue Root’ is used at this stage following the conventions in the literature, without claim to the specific articulatory correlates of the distinction between pairs of similar vowels.

The ATR category of a vowel is important in vowel harmony processes, described in 3.4.3.1; in general, there is a preference for vowels in a word to be of the same ATR

[2]Apart from one example given with /ʊ/.

category, and [+ATR] vowels are dominant, prompting [-ATR] vowels to become [+ATR] via leftward-spreading harmony across roots and affixes. The open vowel /a/, which has been categorised as [-ATR] based on how it interacts with these processes, can occur with both [+ATR] and [-ATR] vowels but, impressionistically, is not realised as qualitatively different in [+ATR] contexts, and also blocks the spread of vowel harmony across the word. The implementation of ATR harmony is mediated by other segmental factors, discussed further in 3.4.3.1. Vowel harmony has not previously been explored for Lopit; Vossen (1982, p. 193) observes only that it plays an important role in all varieties in the Lotuxo family, with many examples of category shift, while Turner (2001, p. 41) similarly notes that ATR harmony is present, and tentatively suggests the possibility of right-to-left harmony, while emphasising the need for investigations of Lopit phonology. The harmony patterns described for Lopit in 3.4.3.1 have much in common with those found in many other Eastern Nilotic languages, for example in the descriptive works referred to above. Across the Eastern Nilotic languages, very little phonetic work has taken place to examine the nature of ATR; to my knowledge, acoustic and articulatory data has so far only been reported for Maasai and Ateso, plus a small amount for Kuku. This is discussed, alongside results for other languages, in the following sections.

4.2.3 Articulatory correlates of ATR

While many early grammars of African languages note that monophthongs in the vowel inventory appear to fall into two distinct sets, the distinction in these works is generally described in terms of a higher or closer quality for one set compared to a lower or more open quality for the other, for example in descriptions of the Eastern Nilotic languages Bari (Spagnolo, 1933) and Maasai (Tucker & Mpaayei, 1955).[3] Some early works also include remarks suggesting possible voice quality differences, sometimes a 'breathy' or

[3]The use of the terms 'close' and 'high' in literature of this sort is to some extent based on assumptions about tongue height and jaw aperture, but in contemporary work the terms are also often used as more agnostic descriptors of auditory quality. It is worth noting that the vowels produced with closer tongue and jaw position are those typically accompanied by a more open laryngeal/pharyngeal passage, and vowels produced with a more open tongue and jaw position are those which require a narrower laryngeal configuration, as will be further discussed.

'hollow' quality for one set compared to a modal or 'hard' or 'creaky' quality for the other (Berry, 1955, Tucker & Bryan, 1966). This is returned to below, and in 4.2.4. The suggestion that different tongue root gestures may be a significant contributor to these distinctions was first explicitly put forward in the 1960s. In his seminal work on the phonetics of West African languages, Ladefoged (1964) provided traces of the tongue body during the production of Igbo vowels, based on stills from cineradiographic data, and observed that for pairs of similar vowels, rather than differences in tongue height, there were striking differences in the degree of tongue body retraction for the vowels typically considered to be less raised. This prompted Stewart (1967) to propose, with reference to his own impressions of vowel contrasts in Niger-Congo Akan, that the description of vowel inventories in Akan and other African languages would be better served by a distinction based on the advanced compared to non-advanced position of the tongue root, specifically (as opposed to 'tense'/'lax' descriptors applied to Germanic vowels, and their associations with height). The idea of tongue root advancement as a significant articulatory mechanism in vowel systems received support, also for its usefulness as an additional feature to supplement traditional descriptions of vowels based on height, backness and rounding (Pike, 1967; Halle & Stevens, 1969/2003).

In radiographic work that followed, Lindau and colleagues set about investigating to what extent tongue root advancement, as a proposed feature of vowels, reliably correlated with a lingual gesture to that effect (Lindau et al., 1972; Lindau, 1975, 1976, 1979). Articulatory data for Asante Twi, an Akan variety (also from Painter, 1973), as well as for Igbo and Ịjọ, point towards tongue root advancement versus non-advancement (or active retraction) as the primary articulatory gesture distinguishing pairs of similar vowels, resulting in greater pharyngeal volume for the advanced tongue root set of vowels. In addition to lingual differences, there was evidence of larynx lowering contributing to further enlargement of the pharyngeal cavity (Lindau, 1975, 1976, 1979). Based on these findings, Lindau (1979) proposes the phonological feature [Expanded] as a more accurate alternative to [Advanced Tongue Root]. Further support for Lindau's (1979) observations comes from later investigations using Magnetic Resonance Imaging (MRI) to collect data with a speaker of the Asante variety of Akan. Tiede (1996) found that in addition to larynx lowering and pharyngeal width differences in the sagittal dimension, which were previously observable via radiographic imaging, there was evidence of pharyngeal expansion in the transverse dimension. Tiede notes that if pharyngeal expansion were a direct result of tongue root advancement only, it would be most noticeable in the sagittal dimension, but observes that the difference in transverse width is almost as great as that of the sagittal depth, indicating that Akan vowel contrasts require speakers to actively control overall pharyngeal aperture. Furthermore, Tiede suggests that Akan speakers actively minimise the concomitant tongue-raising effects of tongue root advancement, which involves contraction of the posterior genioglossus, by using contraction of the anterior genioglossus to maintain relatively constant tongue dorsum height for pairs of [+/-ATR] vowels (Tiede, 1996).

The results of transnasal laryngoscopy studies of Akan and Kabiye, which is also conventionally described as having an ATR distinction, indicate that observed differences in pharyngeal aperture are directly driven by changes in laryngeal configuration (Esling, 2005; Edmondson & Esling, 2006; Edmondson et al., 2007; Edmondson, 2009). Findings show that the articulatory basis of the distinction relates to the overall degree of constriction at a series of points in the lower vocal tract, specifically aryepiglottic sphinctering, tongue retraction and larynx raising, with possible narrowing of the pharyngeal wall, for one set of vowels compared to the other. Furthermore, in the same studies, evidence from diverse other languages described as utilising ATR, phonatory, register-based or pharyngeal differences (Somali, Bor Dinka, Bai, Yi, Arabic) shows the crosslinguistic relevance of a combination of these settings together with those for ventricular incursion and degree of glottal adduction in giving rise to an overall level of constriction as a linguistically salient parameter. In addition, language-specific differences in the engagement (and degree of engagement) of the different valves described by Edmondson and Esling (2006) are proposed to account for the inconsistently observed percepts of phonation differences (e.g. breathiness, creakiness) accompanying proposed ATR distinctions across languages, which may also vary for individual speakers, or speakers of different varieties of a language. It is suggested that the feature [constricted] may best capture the observed overall differences in constriction resulting from the combined series of postures (Esling, 2005; Edmondson et al., 2007). However, the label ATR remains the most widely used in discussions of African vowel systems.

Many recent studies have investigated the lingual gestures associated with vowels described as [+ATR] and [-ATR]/[RTR] using mid-sagittal ultrasound tongue imaging, a non-invasive approach which offers a safer alternative to earlier radiographic techniques, and which also permits real-time imaging of speech produced at a natural rate (Stone, 2005).[4] While the position of an ultrasound transducer held beneath the chin does not permit imaging of the whole vocal tract, it is possible to obtain good images of the shape of the tongue, including the posterior, with this technique. The captured images can offer an indication of any differences in the pharyngeal cavity which may result from adjustments lower down in the vocal tract. The larynx itself is not typically imaged in mid-sagittal ultrasound. These techniques have been applied to reasonably well-described languages in order to answer phonological questions that relate not only to how vowel contrasts are produced, but also to differing claims about the implementation of harmonic processes. Ultrasound investigation of Kinande vowels has established that pairs of mid and close vowels involved in the cross-height harmony system are distinguished by systematic differences in tongue root position, most strikingly so for the paired close vowels, which are lexically contrastive as well (Gick et al., 2006). Existing work on Kinande has been divided as to whether the open vowel /a/ has a [+ATR] counterpart; some authors suggest that /a/ is phonologically neutral and transparent, being largely unaffected by harmony processes spreading beyond it. However, Gick et al. (2006) find acoustic and articulatory evidence that /a/ does have a harmonic counterpart, [ə], and that the categorical change in production involves tongue root advancement. This finding is particularly interesting given that the status of the open vowel, and possible harmonic counterparts, is disputed or poorly understood in many African languages, and illustrates the value of an instrumental approach. In an ultrasound study of Wolof, Dye (2015) investigates whether the close vowels /i, u/, which have similarly been

[4]For the MRI data discussed above, imaging was based on sustained vowel productions due to the low frame rate, but high-speed MRI has since become available (though it remains less widely accessible as a tool in speech research).

described by some authors as transparent to ATR harmony, still show at least low-level phonetic effects depending on the harmonic environment. In this case, no systematic change in production was observed. The study also established the relevance of a tongue root gesture distinguishing proposed [+ATR]/[-ATR] mid vowels in Wolof, and, based on acoustic and articulatory data, raised questions about the robustness of the ATR contrast described for the Pulaar language, in addition to illustrating that a language's preference for left-to-right or right-to-left vowel harmony may lead to possible differences in vowel-to-vowel coarticulation.

Ultrasound data has also been presented for Dagbani, and verifies that proposed [+ATR] vowels do indeed show systematic tongue root advancement in comparison to the class of vowels described as [-ATR] (Hudu, 2010, 2014). Results also show that changes from [-ATR] to [+ATR], as a result of vowel harmony, are categorical; the realisation of underlyingly [+ATR] vowels is the same as that for [+ATR] vowels arising as a result of vowel harmony, and [+ATR] vowels arising from harmony do not differ in their realisation depending on their distance from the trigger of [+ATR] harmony in the word (and are thereby fully assimilated, rather than coarticulated only in proximity to [+ATR] vowels). This accords with acoustic results for Maasai, discussed further in 4.2.4, similarly demonstrating that the assimilation is complete (Quinn-Wreidt, 2013). Hudu (2010, 2014) also explores the 'Direct Mapping Hypothesis'; according to this, the phonologically dominant feature in a vowel harmony system, which for Dagbani is [+ATR], should have a unique and predictable gestural correlate compared to the recessive feature. A useful baseline from which such a gesture might be measured is the rest position of the tongue in between utterances, or Inter-Speech Posture (ISP), which has elsewhere been suggested to have a language-specific default setting (Gick, Wilson, Koch & Cook, 2004). The Dagbani results are interpreted as providing some evidence for this, in that they show all [+ATR] vowels to consistently have a significantly anterior tongue root position relative to the ISP; [-ATR] vowels have a tongue root position which is still significantly more anterior, but less so, for four speakers, and significantly posterior for one speaker (Hudu et al., 2009; Hudu, 2010, 2014). In a study of Yoruba vowels, Allen, Pulleyblank and Ajíbóyè (2013) contribute ultrasound data to debates regarding the articulatory nature of contrasts among the Yoruba mid-vowels /e, o/ and /ɛ, ɔ/, and demonstrate that the difference is clearly dependent on tongue root position rather than tongue height. In addition, Allen et al. (2013) test the evidence for the 'Direct Mapping Hypothesis' in the Yoruba vowel system, which is described as having phonologically active tongue root retraction, rather than advancement, and would be predicted to therefore show a significantly and consistently retracted tongue root position relative to the ISP. The authors find mixed results; among the mid vowels, for which the ATR difference is contrastive, three of six speakers have RTR vowels with a significantly retracted tongue root position compared to the ISP, for one speaker the ISP and RTR tongue root positions are equivalent, and for two, the RTR positions are more advanced than for the ISP. Allen et al. (2013) suggest that this variability indicates at least that the 'Direct Mapping Hypothesis' does not have exclusive influence over the relationship between phonological markedness and the ISP, and various factors such as individual speaker behaviour will need to be considered in further work. It is worth noting that this is true of ATR vowel production in general; the more time-consuming nature of articulatory studies has meant only small numbers of participants were involved in the studies discussed in this section, and the potential for different articulatory strategies is not well understood.

It is not yet clear to what extent these sorts of findings relate to the many other languages in which [ATR] vowel contrasts are attested, particularly because the studies of ATR discussed above are almost all based on West African Niger Congo languages, which may have somewhat different systems to those found in East African Nilo-Saharan languages, and languages elsewhere. Lindau et al. (1972) compare radiography data for Akyem Asante Twi and Igbo (Niger-Congo languages in the Atlantic-Congo group) with data for Dholuo and Ateso (Nilo-Saharan Nilotic languages), all four of which have vowel harmony systems that seem structurally similar. The researchers investigate the feasibility of representing the "same phonological rule" with a uniform feature so that the structural similarities could be represented in the grammatical descriptions of languages. They find that the articulatory mechanism behind the vowel harmony feature is not the same across languages; "in Twi and Dho-Luo the articulatory mechanism is Advanced Tongue Root, in Ateso it is Tongue Height, and in Igbo it is partly Advanced

Tongue Root, partly Tongue Height" (1972, p. 90). However, these different articulatory mechanisms achieve similar acoustic effects, a finding which leads the authors to propose an abstract phonological 'cover feature'[5] for vowel harmony in African languages, with different underlying articulatory realities for individual languages. It is worth noting that so far Ateso (spoken in Uganda and Kenya) is the only Eastern Nilotic language for which any articulatory investigations have taken place, and it will be very interesting to discover whether the apparent importance of raising of the tongue body rather than advancement of the tongue root holds true for other Eastern Nilotic languages such as Lopit. In his phonology sketch of Lopit, Turner (2001, p. 41) mentions that Lopit speakers describe the [+ATR] vowels as "heavy" and notes that they say that "the sound is squeezed by the back of the tongue" for these vowels.

In a more detailed exploration of Dholuo vowel harmony, Jacobson (1978) reiterates the usefulness of a phonological 'cover feature' to refer to similar phonological effects achieved through different articulatory means, particularly because he finds that in Dholuo, either tongue height or tongue root/pharynx width can be used to distinguish the different categories of vowels, and different Dholuo speakers vary in the extent to which they draw on a given articulatory mechanism to make the contrast. Comparing his findings to those of the previous studies discussed above, Jacobson surmises that in West African languages, the mechanism for distinguishing vowel harmony categories may be more uniform than in East African languages, and emphasises that "in comparing several African vowel harmony languages, it will have to be borne in mind that the same phonological cover term may have different phonetic consequences in different languages" (1978, p. 82). These remarks are bolstered by the more recent articulatory evidence, discussed earlier in this section, pointing towards the functional use of overall differences in the degree of constriction as achieved by language-specific adjustments to the articulatory parameters of the lower vocal tract (Esling, 2005; Edmondson & Esling,

[5] They also investigate the claim that "the so-called tense vowels in English and other Germanic languages differ from the so-called lax vowels in the same way as the vowels differ in the vowel harmony sets of African languages" ('tense' being similar to [+ATR] and 'lax' similar to [-ATR]). While they find some similarities and propose that one 'cover feature' could be used for [+/-ATR] and tense/lax, later articulatory work (Tiede, 1996) has found that [ATR] vowel production is quite distinct from tense/lax vowel production.

2006; Edmondson et al., 2007; Edmondson, 2009), and the ways in which laryngeal gestures and their resonance effects interact with lingual gestures and their resonance effects to jointly contribute to spectral differences between vowels (see also Moisik, 2013). Jacobson's findings, and others discussed in this section, highlight the need for more articulatory investigations of putative [ATR] distinctions across a range of languages beyond the canonical Niger-Congo examples, including Nilo-Saharan languages of East Africa and various groups of languages spoken in Asia, such as Tibeto-Burman, Mon-Khmer and Tungusic languages. They also point towards the likelihood that inter-speaker variation exists in the production of these vowel contrasts, which, though articulatory studies typically only involve small numbers of speakers, should be explored where possible.

4.2.4 Acoustic and auditory correlates of ATR

There have been more acoustic analyses of the characteristics of vowel systems with possible [ATR] contrasts than there have been articulatory analyses, and although the picture is far from complete, certain crosslinguistic patterns have emerged. The most consistent finding is that [+ATR] vowels and [-ATR] vowels differ in terms of the first formant frequency (F1). Lower F1 values have been observed for [+ATR] vowels compared to their [-ATR] counterparts in a large number of Niger-Congo and Nilo-Saharan languages (e.g. Lindau & Ladefoged, 1986; Hess, 1992; Local & Lodge, 1996; Fulop, Kari & Ladefoged, 1998; Przezdziecki, 2005; Casali, 2008; Starwalt, 2008). As noted in 2.3.2, among Nilo-Saharan languages, this result has been noted for the vowel systems of several Western Nilotic languages, such as Acholi (Denning, 1989), Dholuo (Jacobson, 1978; Swenson, 2015), and Shilluk (Remijsen et al., 2011), as well as languages such as Maa (Guion et al., 2004) and Ateso (Lindau, 1975), which, like Lopit, are part of the Eastern Nilotic language family. This accords well with the many impressionistic remarks in the literature that [+ATR] vowels have a closer quality, and [-ATR] vowels a more open quality. For Maa, Quinn-Wreidt (2013) also provides quantitative evidence that the F1 difference between the [+ATR] and the [-ATR] set is the same regardless of whether the [+ATR] vowels occur in a context where they are the result of harmony processes or not, and, if they are the result of harmony, regardless of the distance from the [+ATR] vowel triggering the process. This is to be expected if vowel harmony is assumed to be categorical, but has received little attention in the literature on [ATR] contrasts and harmony processes.

Given the articulatory findings demonstrating overall differences in pharyngeal cavity size and associated gestures for one set of vowels compared to another, as discussed in 4.2.3, these acoustic results can be expected; an increase in the size of the pharyngeal cavity will produce lower resonant frequencies for the first formant, while constriction will lead to higher F1 values. However, these acoustic differences can also be achieved via supralaryngeal gestures occurring without additional constriction differences further down in the vocal tract, given that lower first formant frequencies also correlate with higher tongue body positions. For example, as noted above, Lindau et al. (1972) find that although the articulatory mechanisms behind the [ATR] contrast vary for Ateso, Igbo, Dholuo and Twi, the different mechanisms achieve similar acoustic effects, and result in vowels with comparable characteristics in the F1/F2 space. Furthermore, the authors note that the relative lowering/raising of F1 for different vowels is affected by the magnitude of the gestural adjustments to pharyngeal width compared to tongue body position; there may be observable differences in both, but one may cause greater F1 movement than the other. On the whole, then, F1 differences correlate well with the [ATR] phonological feature but the specific strategies used to produce these may vary, and require instrumental examination.

In languages described as having [ATR] contrasts, distinctions between [-ATR] close vowels /ɪ/ and /ʊ/ and [+ATR] close-mid vowels /e/ and /o/ (referred to here as close/mid pairs) are also of particular interest; as Casali (2008, pp. 508–510) notes, in impressionistic descriptions of ATR systems, it has often been observed that the vowels in these pairs are difficult to distinguish auditorily, at least for non-native speakers. He emphasises that this has had major implications for vowel analyses based on linguistic fieldwork, and observes that a good number of African languages with contrastive /ɪ/ and /ʊ/ have previously been analysed as having fewer vowel phonemes than more recent work has uncovered, as a result of difficulties in hearing and accurately transcribing height differences between these and /e/ and /o/. Some studies of Niger-Congo languages have demonstrated that there is overlap on the basis of F1 values for /ɪ, e/ and also for /ʊ, o/

in at least some languages (Hess, 1987; Anderson, 2003), while others have shown mixed results, with with F1 being significantly different for the pairs in some languages, but not necessarily for all speakers (Starwalt, 2008). This is similar to findings reported by Guion et al. (2004) for Eastern Nilotic Maa; of five participants, only two used F1 to distinguish /ɪ/ from /e/ and three used F1 to distinguish /ʊ/ from /o/. In all these studies, however, the possibility of other acoustic or durational correlates to the distinction is raised, as discussed further below.

Some studies have also found evidence that the second formant (F2) differs in pairs of [+ATR] and [-ATR] vowels. However, the nature of the findings varies across languages, and where F2 differences have been noted, they are not always relevant for all vowel pairs. Ladefoged and Maddieson (1996b, pp. 304–305) observe, with reference to F1/F2 vowel spaces for Akan, Ateso, Dholuo, Ebira, Igbo and Ijo, that [+ATR] vowels tend to be both more raised and advanced in the acoustic space, i.e. that [+ATR] vowels have higher F2 values than the corresponding [-ATR] vowels. As they point out, this is one source of difference between the ATR systems of African languages and the Tense/Lax vowel contrasts of Germanic languages, in which 'tense' vowels are more peripheral than 'lax' vowels of similar qualities, and the direction of F2 difference therefore depends on whether they are front or back vowels. However, the pattern of uniformly higher F2 values for [+ATR] vowels does not hold across languages. In Degema, F2 values are higher for [+ATR] front vowels /i/ and /e/ than [-ATR] /ɪ/ and /ɛ/, while for [+ATR] back vowel /o/, F2 values are lower than for [-ATR] /ɔ/, and no F2 differences were found for /u, ʊ/ and /ə, a/. For Maa, there is a similar trend, though non-significant, of higher F2 values for [+ATR] /i, e/ compared to [-ATR] /ɪ, ɛ/, but no differences among back vowels. In a study of the acoustic correlates of ATR in eleven languages, Starwalt (2008) concludes that the role of F2 is "ambiguous"; in most cases, F2 differences vary across speakers and vowel pairs within each language. Though a pattern of higher F2 values for [+ATR] front vowels compared to [-ATR] front vowels was observed for a number of languages, any patterns for back vowels were much less consistent. For example, in results for Kinande, there are no F2 differences among back vowel ATR pairs, while in Lubwisi, /u/ tends to have higher F2 values than /ʊ/, and for Ekiti, [+ATR] /u/ also tends to have higher

F2 than [-ATR] /ʊ/, but [+ATR] /o/ tends to have lower values than those for [-ATR] /o/. In Foodoo, /u/ is instead more peripheral, and has lower F2 values than [-ATR] /u/, while the vowel space for Ife is the only one which shows the classic 'V-shape', and in which all [+ATR] vowels are more peripheral than [-ATR] vowels. Interestingly, for Nilo-Saharan Shilluk, it seems that the [-ATR] vowels may in some cases be more peripheral, notably for close front [-ATR] /ɪ/ compared to [+ATR] /i/ (Jacobson, 1980; Remijsen et al., 2011). It seems, then, that where F2 differences are observed, anything is possible; there is no crosslinguistically reliable pattern. Where the close/mid pairs /ɪ, e/ and /ʊ, o/ have been compared, patterns for F2 are similar as for F1: the values for each pair frequently overlap, but differences are sometimes observed for individual languages and speakers (Hess, 1987; Anderson, 2003; Guion et al., 2004; Starwalt, 2008).

Results for the third formant (F3) have rarely been reported in phonetic studies of ATR, but it might be expected that, where there are F2 differences, some F3 differences may also be present, given the relationship between F2 and F3. Alternatively, F3 could help to disambiguate vowels in occasional cases where F1 does not significantly differ between particular pairs of [+ATR] and [-ATR] vowels, such as when some close and mid back vowels appear to be crowded in the vowel space (e.g. Noonan, 1992). Some F3 values are reported by Hess (1987) for Akan, and differ for at least some ATR pairs, with higher F3 values observed for /i/ compared to /ɪ/, as well as for /o/ compared to /ɔ/. For the Tungusic language Even, Aralova et al. (2011) observe a general pattern of lower F3 values for vowels of the 'retracted' compared to 'advanced' tongue root set in one of the two dialects studied, and suggest that this relates to pharyngealisation for these vowels. These findings, and others discussed above, underscore the need to consider the ways in which both the upper and lower parts of the vocal tract work together to maintain meaningful spectral differences between vowels.

Formant differences may not be the only cues to ATR contrasts; as noted in 4.2.3, alongside impressionistic remarks in early work of a closer quality for [+ATR] compared to [-ATR] vowels, many authors note impressions of possible differences in phonation, voice quality, timbre, or some other percept beyond auditory vowel height and backness. For a number of African languages, vowels now labelled [+ATR] have sometimes been described with terms such as 'hollow', 'breathy', 'dull', 'muffled', 'full', and 'deep', while vowels now labelled [-ATR] have variously been referred to as 'tight', 'creaky', 'hard', 'brassy', 'choked', 'strangled' (e.g. Berry, 1955; Tucker & Bryan, 1966 Stewart, 1967; Pike, 1967; Welmers, 1973). Similar descriptors have also been used for languages elsewhere with vowel inventories which are phonologically similar; for example, vowel inventories in Mon-Khmer languages which are now often referred to as having register-based distinctions have been described as having one set of vowels perceived as 'breathy', 'deep', 'sepulchral', 'lax' compared to another perceived as 'clear', 'normal', 'guttural', 'tense' (e.g. Gregerson, 1976). Note that in the latter case, the terms 'tense' and 'lax' are used in a different (essentially opposite) sense to their application in the description of Germanic languages, though the Germanic sense has also been applied to the description of African languages in some cases (Jakobson & Halle, 1962).[6] In 2.3.2 it was noted that similar impressions have been recorded for vowels in a number of Western Nilotic languages (aside from those in which phonation is contrastive), as well as some Southern and Eastern Nilotic languages. For Eastern Nilotic languages, Tucker and Bryan (1966, p. 444) note that the 'close' vowels in Bari, Maasai, Teso and Otuho have a "hollow" voice, compared to a "hard" voice for the 'open' set of vowels, while Coates (1985, p. 97) observes that Otuho [-ATR] vowels tend to sound more creaky than [+ATR] vowels. For Turkana, Dimmendaal (1983b, p. 18) comments that the [+ATR] vowels "sound somewhat breathy" (apart from [+ATR] mid vowels in the environment of specific [-ATR] vowels) and that the [-ATR] vowels have a "hard" voice, or sound "tense" or "harsh" (Dimmendaal, 1983b, p. 27).

Phonetic evidence for these types of auditory impressions has been sought in explorations of any differences between [+ATR] and [-ATR] vowels in terms of the energy distribution in the spectrum. Various measures have been used to explore energy characteristics correlating with a range of phenomena in the world's languages, and terminology differs, but as proposed by Heldner (2003), these tend to fall into two classes: 'spectral

[6] The terms 'tense' and 'lax' are more articulatorily appropriate in their application to Tibeto-Burman languages, given that 'tense' in these cases refers to the behaviour of an articulator which can be 'tensed' or constricted. In addition to duration, Germanic vowel contrasts rely more on jaw aperture and lingual position within the oral cavity.

tilt' measures which explicitly represent the slope of the spectrum, and 'spectral emphasis' measures which calculate the relative energy in the higher frequency bands. In the study of [ATR] contrasts, the former have been more often applied. To investigate spectral slope differences in Degema vowels, Fulop et al. (1998) use a measure of normalised second formant amplitude subtracted from normalised first formant amplitude (*A1-A2). To minimise the effects of different vowel qualities, reference A1-A2 values were first modelled, and these were subtracted from the observed A1-A2 values. Fulop et al. (1998) note that while some of the impressionistic voice quality differences noted for African languages may relate to actual differences in phonation, some may be concomitant effects of other aspects of ATR articulation, e.g. formant damping when the pharynx is more constricted. They find that Degema [+ATR] vowels have higher *A1-A2 values in general, suggesting the slope of the spectrum falls off more steeply for [+ATR] vowels compared to [-ATR] vowels. However, this was only significant for /i/ compared to /ɪ/, and /o/ compared to /ɔ/. The same measure was used by Starwalt (2008) for eleven languages, with mixed results; in just over half of the available [+/-ATR] pairs across all the languages (41 cases), *A1-A2 values were higher for [+ATR] compared to [-ATR] vowels, as for Degema, but in 35 cases there was no difference, and in 5 cases there was a difference, but in the opposite to expected direction. Starwalt (2008, p. 418) suggests that the highly derived nature of this measure may affect the robustness of results. The same measure has been applied to vowels in Eastern Nilotic Maa, and a general trend of steeper spectral slopes for [+ATR] compared to [-ATR] vowels was observed, though these differences were only significant for /e/ compared to /ɛ/ and /u/ compared to /ʊ/ (Guion et al., 2004). The authors note that these spectral differences may have various possible articulatory origins, potentially related to the muscular tension of the pharyngeal walls, the effects of pharyngeal constriction on the amplitude of the first formant, or to differences in phonation. As discussed below and elsewhere, more recent models of the vocal apparatus show that a range of interacting articulatory configurations beyond those affecting the pharyngeal walls are likely involved. The acoustic analysis is followed up with electroglottographic (EGG) results for one speaker, to assess whether the degree of vocal fold contact during a vibratory cycle, as measured by Contact Quotient (CQ, also Closure Quotient) provides any indication of phonatory differences between vowels. Guion et al. (2004) find that across vowel types, Maa [+ATR] vowels for this speaker have smaller CQ values than their [-ATR] counterparts, which can be indicative of a less constricted glottis and therefore breathier phonation (though the precise nature of any constriction in the glottal region can only be reliably ascertained with direct observation of the articulation). Interestingly, this is despite the authors noting that they did not find phonation differences to be readily perceptible among Maa vowels. For Southern Nilotic Tugen, a Kalenjin variety, Local and Lodge (2004) note auditory impressions of a breathy voice quality correlating with one set of vowels, but unusually, with the [-ATR] set rather than the [+ATR] set. While they do not measure spectral slope differences, EGG results for one speaker provide evidence for these impressions.

Spectral emphasis, a measure which has elsewhere been used in investigations of vocal effort (Traunmüller & Eriksson, 2000; Heldner, 2003), has been applied in analyses of vowel contrasts in some Western Nilotic languages. This measure, which takes a low-pass filtered signal to look at the relative contribution of the higher frequency bands to the overall intensity, has been applied to vowel data for Western Nilotic Shilluk (Remijsen et al., 2011), which, as noted in 2.3.2, is described as having five [+ATR] vowels contrasting with five [-ATR] vowels. The [+ATR] vowels are perceived to have a closer quality, and also to be somewhat breathier. Formant frequency data show that, as for many other languages, there are significantly lower F1 values for [+ATR] compared to [-ATR] vowels. In addition, [+ATR] vowels have lower spectral emphasis values, meaning that more of their energy is below 1.5 times the fundamental frequency. The observation that the [+ATR] vowels have proportionally less high-frequency energy than the [-ATR] vowels is in line with an interpretation that they have a breathier voice quality. However, as the authors note, the overlap in the distributions of [+ATR] compared to [-ATR] spectral emphasis values shown to one standard deviation suggests some variability, whereas there is almost a complete lack of overlap in plotted F1 values. Based on this, they suggest that voice quality differences are a secondary correlate only. This is likely to be the case in many languages with an [ATR] contrast; as Casali (2008, p. 510) notes, while on the one hand additional correlates broadly relating to phonation, voice quality or timbre may be more widespread than the literature on African languages suggests, they may also be more subtle than some of the impressionistic labels imply. Returning to the results of articulatory studies discussed in 4.2.3, and in particular the insights offered by laryngoscopic examination of vowel phenomena, this is perhaps not surprising; while adjustments to the aryepiglottic stricture, degree of tongue retraction, larynx height and pharyngeal width, as observed for [+/-ATR] vowels in Akan and Kabiye, may have acoustic effects which are perceived as differences in voice quality or timbre, these may or may not co-occur with ventricular incursion, as observed for 'harsh' or [-ATR] vowels in Somali, or a lesser degree of glottal adduction, as for 'breathy' vowels in Dinka, in which phonation is contrastive, but historically connected to [ATR] distinctions in related languages (Esling, 2005; Edmondson & Esling, 2006; Edmondson et al., 2007; Edmondson, 2009). It is to be expected that there will be language-specific implementations of these overall differences in constriction, and that different combinations of cues will be used to support contrasts, though there is a need for the small body of acoustic work in this area to be supplemented by more exploration of both the articulatory and perceptual correlates of putative [ATR] distinctions in each language on order to understand the ways that speakers and listeners make use of the mechanisms available to them.

Duration values have not been included in many studies of ATR correlates. Though in some cases the vowel systems of African languages have been described as utilising 'tense' vs. 'lax' distinctions, in a similar way to Germanic languages (Jakobson & Halle, 1962), it is noted that while the resulting auditory vowel qualities may be similar, differences include the lack of audible duration differences between the [+ATR] and [-ATR] sets, unlike between the 'tense' and 'lax' sets of Germanic languages (e.g. Stewart, 1967). Nevertheless, vowels of differing qualities are often found to have inherently different duration tendencies, so it is possible that these may sometimes be additional cues. For Akan, Hess (1987) reports slightly longer (around 10ms) mean durations for tokens of [+ATR] /i/ and /e/ compared to [-ATR] /ɪ/ compared to [-ATR] /ɛ/ (the duration of other vowel qualities was not measured). However, she notes that as there is also overlap in the distribibion of values for each pair, it would be difficult for this to be used as a cue to ATR category. A tendency towards slightly longer durations for [+ATR] vowels is also noted for Tugen, a Kalenjin variety on the Southern Nilotic family (Local & Lodge, 2004). Conversely, Przezdziecki (2005) finds that in one Yoruba variety, the [-ATR] front vowels are significantly longer than the [+ATR] front vowels, while for two other Yoruba varieties, similar but non-significant trends of longer durations were noted for the [-ATR] mid vowels. Starwalt (2008, p. 78) finds no particular pattern correlating duration with [ATR] distinctions in her study of 11 Niger-Congo languages. It is worth noting that some of these languages separately make use of contrastive length within the vowel system, which may limit the likelihood that duration is also a salient cue to [ATR] quality. For Eastern Nilotic Maa, vowel duration was included as a measure given speculation from Ehret (2001) that Proto-Eastern Nilotic had [-ATR] /ɪ/ and /ʊ/ as reflexes of the short vowels /i/ and /u/ he reconstructs for Proto-Nilo-Saharan, while Proto-Eastern Nilotic [+ATR] /i/ and /u/ are suggested to derive from the long vowels /iː/ and /uː/ which are also reconstructed. However, results for Maa show no duration differences at all for pairs of [+ATR] compared to [-ATR] vowels, for any speakers; the only significant difference of interest is that [+ATR] /o/ was significantly longer than [-ATR] /ʊ/, to which it is spectrally and impressionistically similar.

4.3 Hypotheses

From the literature discussed above, and relevant discussion found in Chapter 2 and Chapter 3, a number of key points emerge for consideration in investigating the phonetic characteristics of Lopit monophthongs, and generally pertaining to the study of 'Advanced Tongue Root' contrasts. These have informed the approaches to the research questions which are the focus of this chapter: Research Question 2, "What are the acoustic correlates of vowel contrasts found in Lopit?" and Research Question 3, "What sorts of articulatory mechanisms are involved in producing Lopit vowel contrasts?" Four hypotheses were developed for testing in the two production experiments discussed here, and the motivations for these are discussed below.

Among the vowel contrasts put forward in 3.4 and returned to above in 4.2.2, nine monophthongs were proposed for Lopit, and, based on phonological analyses, eight of these were observed to form four pairs sharing similar vowel qualities, with relevance for the vowel harmony processes discussed in 3.4.3.1. The four vowels /ɪ, ɛ, ɔ, ʊ/, which have been referred to as [-ATR], have counterparts /i, e, o, u/, which have been referred to as [+ATR], drawing on the concept of 'Advanced Tongue Root' as a phonological feature of significance in Nilotic languages. Crosslinguistically, the most consistent finding in terms of the phonetic correlates of ATR is that [+ATR] vowels have lower first formant frequencies compared to [-ATR] vowels. Some differences in the second formant, third formant, energy distribution, and duration have also been observed, but results have varied, and additional correlates appear to have more language-specific than general relevance. Based on these overall findings, it is hypothesised that:

1. In Lopit, the [+ATR] vowels /i, e, o, u/ are acoustically distinguished from their harmonic counterparts in the [-ATR] set /ɪ, ɛ, ɔ, ʊ/ primarily by lower F1 values, but with additional cues provided by F2, F3, spectral emphasis and duration.

In terms of articulation, early radiographic imaging followed by later MRI, laryngoscopic and ultrasound imaging has shown that for a number of Niger-Congo languages, corresponding vowels in the two classes have distinct articulatory gestures. Vowels which are typically labelled [+ATR] in the current literature differ from those labelled [-ATR]/[RTR] by having a more advanced position of the tongue root, and related gestures including greater pharynx width and a lower larynx position (4.2.3). Articulatory studies of Nilo-Saharan vowel systems are more limited, and while radiographic work has found that differences in tongue root position may be observed to some extent for particular vowel contrasts, or by particular speakers, manipulation of tongue height also appears to be a strategy for differentiating [+ATR] and [-ATR] vowels in these languages. Despite this possible variability in Nilo-Saharan languages, the crosslinguistic findings lead to a hypothesis that:

2. The Lopit [+ATR] vowels /i, e, o, u/ are articulatorily distinguished from their harmonic counterparts in the [-ATR] set /ɪ, ɛ, ɔ, ʊ/ by differences in the lingual gesture used in production, with [+ATR] vowels showing a more anterior tongue root position.

In descriptions of many African languages with ATR contrasts attested, there are often impressionistic remarks that the [+ATR] mid vowel /e/ is perceptually very similar to the [-ATR] close vowel /ɪ/, and the [+ATR] mid vowel /o/ is perceptually very similar to the [-ATR] close vowel /ʊ/, at least to the ears of non-native-speaking researchers. It has been suggested that these close/mid pairs may be more similar to each other than vowels in harmonic pairs, and in some of the phonetic studies noted, F1 and F2 values for the vowels in each pair show some overlap in the vowel space. Some similar impressions were noted in 3.4 for Lopit monophthongs with these qualities, but also with phonological evidence that they contrast in Lopit. Given this, it is hypothesised that:

3. Similar F1 and F2 values will be observable for the vowels in the close/mid pair /ɪ, e/, as well as for the vowels in the close/mid pair /ʊ, o/, but the vowels in each pair will be still be distinct on the basis of formant values and supporting correlates.

As described in 2.3, and noted above, for Eastern Nilotic languages, 10-vowel systems are described for some of the Bari languages, but among the non-Bari languages, 9-vowel systems are typical. These 9-vowel systems include a [-ATR] open vowel /a/, but /a/ does not have a [+ATR] counterpart (such as /ə/ or /ʌ/) of the sort found in a 10-vowel system. However, in descriptions of many African languages, the status of /a/ and possible allophones is not always clear. For Lopit, Vossen (1982) and Turner (2001) tentatively propose a [+ATR] counterpart to /a/, likely to capture that it can occur with both [+ATR] and [-ATR] vowels (whereas other monophthongs tend to only co-occur with vowels of the same ATR specification). However, they also note their impressions that if there are two distinct 'open' vowels, they are phonetically very similar. Some comments for closely-related Otuho suggest the possibility of a perceptible difference between two such vowels, but this does not appear to be the case in other related languages, such as Maa, for which it has been explored with acoustic data. Given the unlikelihood of two distinct 'open' vowels in Lopit, it is hypothesised that:

4. The phonetic differences between /a/ in the [-ATR] environment and /a/ in the [+ATR] environment, where vowel harmony processes trigger a change in vowel category, will be insufficient to posit that there are two contrastive low vowels.

4.4 Methodology - Acoustic Analyses

4.4.1 Participants

The participants for this production study were four adult male speakers of Lopit (AL, DA, VH and JL). They are all members of the Lopit community of Melbourne, introduced in 1.6.1, and arrived in Australia after 2000. All four participants are from the Dorik dialect area in the Lopit mountains (see map in 1.2), and come from three different villages within this area.

4.4.2 Materials

The stimuli for this production experiment were developed alongside more general data collection as outlined in 1.6.2, which primarily focused on building up a lexical database for Lopit and describing aspects of the segmental and tonal morphology. Given that the documentation of Lopit is still in the very early stages, the pool of lexical items from which experimental stimuli could be chosen was (and still is) relatively small compared to that for languages with more extensive description. However, with the data available, a wordlist was developed which would allow for an investigation of Lopit monophthongs occurring in reasonably comparable phonetic environments, in order to explore the overall vowel system and the specific hypotheses relating to [ATR]. The wordlist contains nouns only, of 2–3 syllables. In the development of the wordlist, tone, word position, and consonantal environment across harmonic pairs were considered to the extent possible with the lexical data available at the time, but as the wordlist shows it is not possible to fully control for these factors at this stage. These matters are taken into account in the statistical analyses which follow.

Words were selected to include 10 examples of each [+ATR] vowel, plus 10 examples of each [-ATR] vowel occurring in a similar context, as well as 10 examples of /a/ in the environment of [-ATR] vowels and 10 examples of /a/ in the environment of [+ATR] vowels, where a harmonic counterpart would be expected to typically occur if indeed it exists. In total, the number of words used for the present analyses was 85 (for some words, two different vowels occurring in the word were used). The list can be found in Table C.2 in Appendix C, and some examples are shown in Table 4.1. Analyses were based on three repetitions of the 10 words for each of the 10 vowels across four speakers, for a total of 1,200 tokens.

Table 4.1: *Examples of wordlist items with [+ATR] and [-ATR] vowels. (The full list can be found in Appendix C.)*

[+ATR]		[-ATR]	
[i]		[ɪ]	
xìɾì	walking stick SG	xíɾí	waterhole SG
xìtó	child SG	xìtɔ̂	scorpion SG
[e]		[ɛ]	
áxéɾí	star SG	íxɛ́rɛ́k	turtle SG
xàtːélí	egg SG	lɔ̀tːɛ́xíʔ	mousetraps PL
[o]		[ɔ]	
tóɾú	axe SG	tɔ́bɔ́k	clay bowl SG
fótír	warthog SG	fɔ́fɔ́ŋ	cactus trees PL
[u]		[ʊ]	
xúɾú	small invertebrates PL	xʊ́tʊ́k	mouth SG
ìxùlóʔ	calabash SG	lɔ̀xʊ́rʊ̀k	raven sp. SG
[a] in [+ATR] context		[a] in [-ATR] context	
xáɾí	rod, switch SG	xáɾí	river SG
xábó	antelope sp. SG	xábʊ́	rainmaker SG

4.4.3 Elicitation and recording procedures

Production data were recorded over several sessions in the recording studio at the University of Melbourne, at a sampling rate of 44.1kHz and 16-bit depth. Participants were asked to produce each of the target words three times in the frame *ebak batak X te ruxulun* 'the pig hit X purposefully'. The frame was selected to ensure that nouns were all produced in the absolutive rather than nominative case, which in Lopit is indicated by a change in the tonal pattern across the word (Moodie & Billington, 2015, and as described in 3.5.2). Frame data were recorded following the elicitation of the same words produced in isolation (for three of the four speakers). Nouns produced in isolation are also realised with the absolutive tonal pattern. For participant JL, it was only possible to record the initial set of isolation data, so the experiment involves frame data for three speakers and isolation data for one. Possible effects of this are addressed in 4.8.

The stimuli were presented to speakers on a notebook computer in slideshow format. For each target word, three slides were displayed, each showing the Lopit word, in the frame noted above,[7] written in the simple working orthography currently being used in practical language materials being developed with the community. This orthography does not indicate ATR vowel quality or tone. The English gloss for each item was displayed beneath. The first slide displayed a small number 1 in the bottom corner, the next 2, and then 3. For each new word, participants were asked to wait until the English gloss had been read aloud, and then produce what was written in Lopit on the screen, just once. They were asked to wait for the click of the mouse moving to next numbered slide before producing the next token of the same word. This enforced brief pause between repetitions was quite effective at minimising pitch declination across repetitions and breathlessness of the speakers attempting to produce all tokens in quick succession, both of which were somewhat apparent in pilot work.

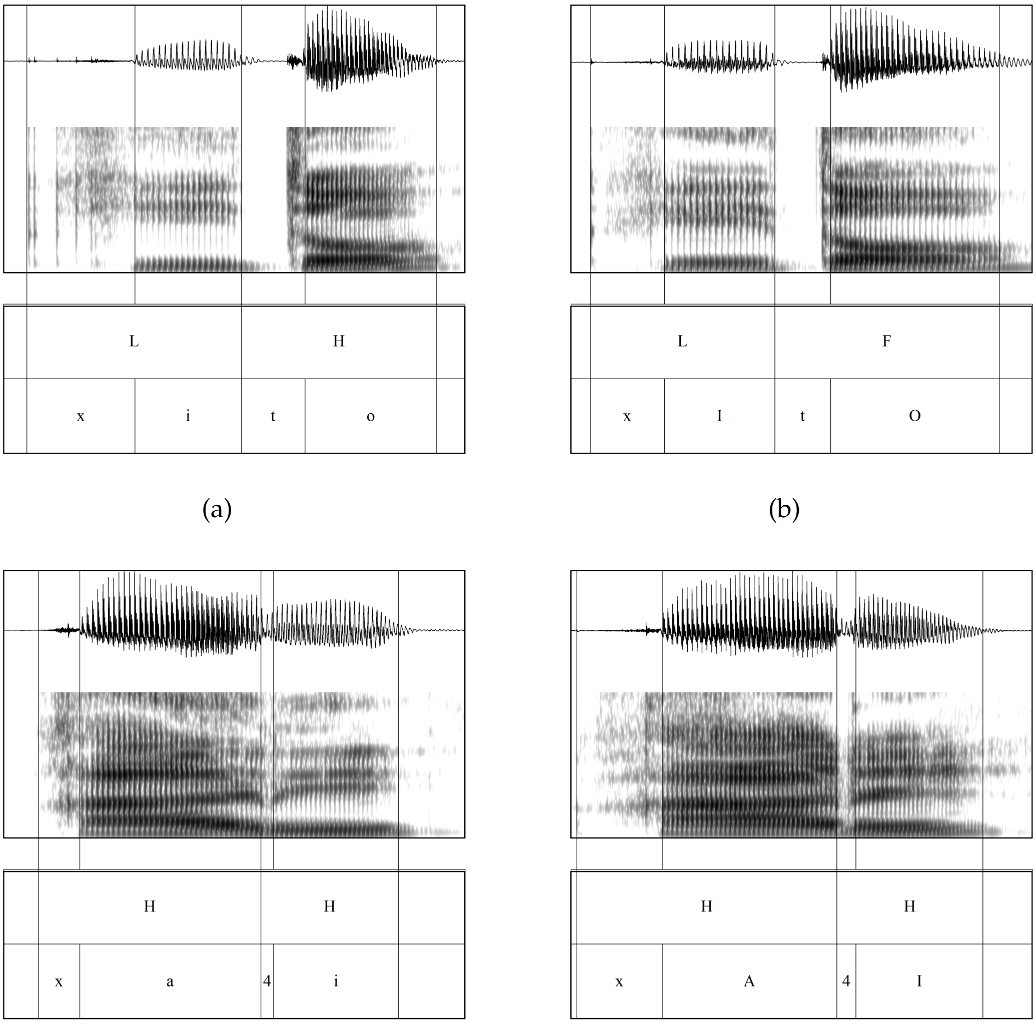
4.4.4 Data processing and analysis

4.4.4.1 Segmentation and labelling

Once recorded, the data were segmented and labelled in Praat with reference to wideband spectrograms and corresponding waveforms (Boersma & Weenink, 2016). Segmental labelling was done using X-SAMPA (Wells, 1995), and was broad phonetic in the sense that vowels were labelled according to surface ATR quality and not the 'underlying' vowel quality before any harmony processes, but in all other respects (e.g. consonantal labelling), it was phonemic. Vowels were segmented according to standard conventions (e.g. Keating, MacEachern, Shryock & Dominguez, 1994; Croot & Taylor, 1995; Turk, Nakai & Sugahara, 2006), with identification based on the portion of the speech signal with

[7] For the isolation data, which is used in analyses for speaker JL, the same format was used, but with five slides and no frame.

both periodicity and continuous formant structure in the upper formants, as shown in Figure 4.1. For the small number of word-final vowels, the final boundary for the vowel was placed where formant structures above F1 became discontinuous. As the focus of this experiment was vowels, and consonantal labelling was phonemic rather than phonetic, release phases are included with the consonant segment, and not separately labelled. The phonemic tone of each syllable was also labelled on a separate tier.



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

Figure 4.1: *Acoustic waveforms and spectrograms showing example tokens and labelling (first two tiers) of (a) /xìtó/ 'child* SG*' and (b) /xìtɔ̂/ 'scorpion* SG*' (duration 750ms, dynamic range 50dB), and (c) /xáɾí/ 'rod, switch* SG*' and (d) /xáɾí/ 'river* SG*' (duration 650ms, dynamic range 50dB).*

4.4.4.2 Acoustic measures

Praat Textgrids were imported to the Emu Speech Database System (Cassidy & Harrington, 2001) to hierarchically link labels in tiers and extract selected acoustic data, and the data were then queried and plotted in the R software environment (R Development Core Team, 2016) using the `emu/R` package (Harrington et al., 2012). The measures of interest in this experiment are F1, F2, F3, Euclidean distance, duration, and spectral emphasis, and were selected in order to inform the overall description of the vowel system and the specific hypotheses discussed earlier.[8] In Emu, frequencies of the first, second and third formants of each vowel, in Hz, were extracted using the Speech Signal Analysis tool, and the formant values at vowel midpoints were then automatically identified for all vowels in R. Euclidean distances were also calculated, using the F1 and F2 midpoint values for each vowel token to identify the distance (in Hz) of each vowel from the overall centre of the F1/F2 vowel space, as a measure of peripherality. Duration values (in ms) for vowels were also extracted in R based on the boundaries of labelled segments. These results were compiled as a data frame which included, in addition to vowel type, additional variables of speaker, word, tone, repetition number, overall ATR category ([+ATR] or [-ATR]), number of syllables (2 or 3), and syllable context type.

In addition, a subset of the recorded and labelled data was selected for use in the analysis of spectral emphasis. This subset comprised vowels in the CVC environment (no initial or final vowels), occurring in high-toned syllables only (to minimise the possible effects of tonal differences on voice quality). The subset is indicated with an asterisk in Table C.2 in Appendix C. There were 12 tokens of each vowel per speaker, for a total of 480 tokens. As noted in 4.2.4, spectral emphasis measures use a low-pass filtered signal to look at the relative contribution of the higher frequency bands to the overall intensity. This was achieved using a modified version of a Praat script written by Mills (2009), who provides an implementation of the measure following that proposed by Traunmüller and Eriksson (2000), as well as a modified version of a Praat script written by Remijsen

[8] Some additional measures of voice quality (e.g. H1-H2) were also explored, but are not discussed; results were much the same as those reported for spectral emphasis.

(2004).[9] The scripted procedure applies a low-pass filter at 1.5 times the f0 mean for the audio segments of interest, and the intensity, in dB, of the filtered signal is then subtracted from the overall intensity. The spectral emphasis results were compiled in a separate dataframe, which included the same variables as the first (apart from tone, given that all tokens had high tones).

4.4.4.3 Statistical tests

The data were tested with Linear Mixed-Effects Models (LMEM) using the `lme4` package in R (Bates, Maechler & Bolker, 2012), following comparisons between different models to see which factors improved model performance, and accompanied by visual checks of variance (homoscedacity) and normal distribution using plots of residuals and fitted values. The main effect of individual vowel category as well as overall ATR category is investigated in this chapter. For tests of F1, F2, and F3, the random effects were speaker, word and tone. For Euclidean distance, number of syllables and syllable type were included in addition to speaker and word. For duration, the random effects were speaker, word, tone, number of syllables, and syllable type. For spectral emphasis comparisons, speaker and word were included as random effects (recalling that for this subset of the data all vowels were in high-toned syllables). The validity of each analysis in this experiment was first checked using a likelihood ratio test, to compare a model including both the fixed and random effects with a model including only the random effects and thereby corresponding to the null hypothesis. The absence of a significant difference between these models indicates that the fixed effect does not have a more substantial influence on the measure of interest than the random effects, and that the relevant hypothesis must be rejected. A difference between the models suggests that the fixed effect does have an influence, and the differences between pairs of glides can then be inspected using Tukey's Honest Significant Difference post-hoc tests. Throughout this chapter, results are reported as Pearson's Chi-Square values (χ^2) and associated p-values, with

[9] My thanks to the authors of these scripts for making them available, with detailed comments, and particularly to Bert Remijsen sharing additional information and advice to assist me in getting started with this measure.

p-values up to 0.05 accepted as significant. The results of the post-hoc tests for comparisons relating to the present hypotheses are summarised in tables throughout. Results for additional key comparisons can be found in Table 4.8, and the results across the full range of vowel comparisons are given in Table D.7 in Appendix D. Descriptive statistics (number of tokens, mean, standard deviation, median, minima, maxima) for F1, F2, F3, Euclidean distance, duration, and spectral emphasis are also contained in Appendix D (Table D.1 to Table D.6).

4.5 Results - Acoustic Analyses

4.5.1 Spectral properties of vowels

4.5.1.1 F1

In Figure 4.2, F1 and F2 values at vowel midpoints are plotted for each of the four participants. An observable pattern is that, in general, the [+ATR] vowels have lower F1 values than their [-ATR] counterparts. The exception is the open vowel /a/, which shows only minimal F1 differences in the context of [+ATR] vowels compared to [-ATR] vowels (plot labels 'a+' and 'a-'). To examine the significance of F1 differences between vowel pairs, the F1 data were first submitted to a likelihood ratio test, which returned a significant result ($\chi^2(9, N=1200) = 2005.7$, $p<0.001$), indicating that vowel category has an effect on F1. Selected results of Tukey's post-hoc tests, summarised in Table 4.2, show a number of significant differences between vowels. F1 values for [+ATR] vowels /i, e, o, u/ are all significantly lower than for their [-ATR] counterparts. F1 is an estimated 67 $\pm$ 9 Hz lower for /i/ compared to /ɪ/, 126 $\pm$ 10 Hz lower for /e/ compared to /ɛ/, 118 $\pm$ 10 Hz lower for /o/ compared to /ɔ/, and 78 $\pm$ 10 Hz lower for /u/ compared to /ʊ/. In addition, F1 differences are also significant for the close/mid pairs of [+ATR] and [-ATR] vowels; in comparisons of /ɪ, e/, [-ATR] /ɪ/ has F1 values an estimated 50 $\pm$ 9 Hz lower than those for [+ATR] /e/, and in comparisons of /ʊ, o/, [-ATR] /ʊ/ has F1 values an estimated 50 $\pm$ 10 Hz lower than those for [+ATR] /o/. For /a/ in the [+ATR] environment compared to /a/ in the [-ATR] environment, there are no significant differences in F1 ($p=1.00$). The main effect of ATR category was also tested, and returned a significant result ($\chi^2(1, N{=}1200) = 503.09$, $p<0.001$). In Table 4.8, it can be seen that significant F1 differences also occur between other pairs where they would be expected, such as between /a/ compared to /ɔ/ and /ɛ/.

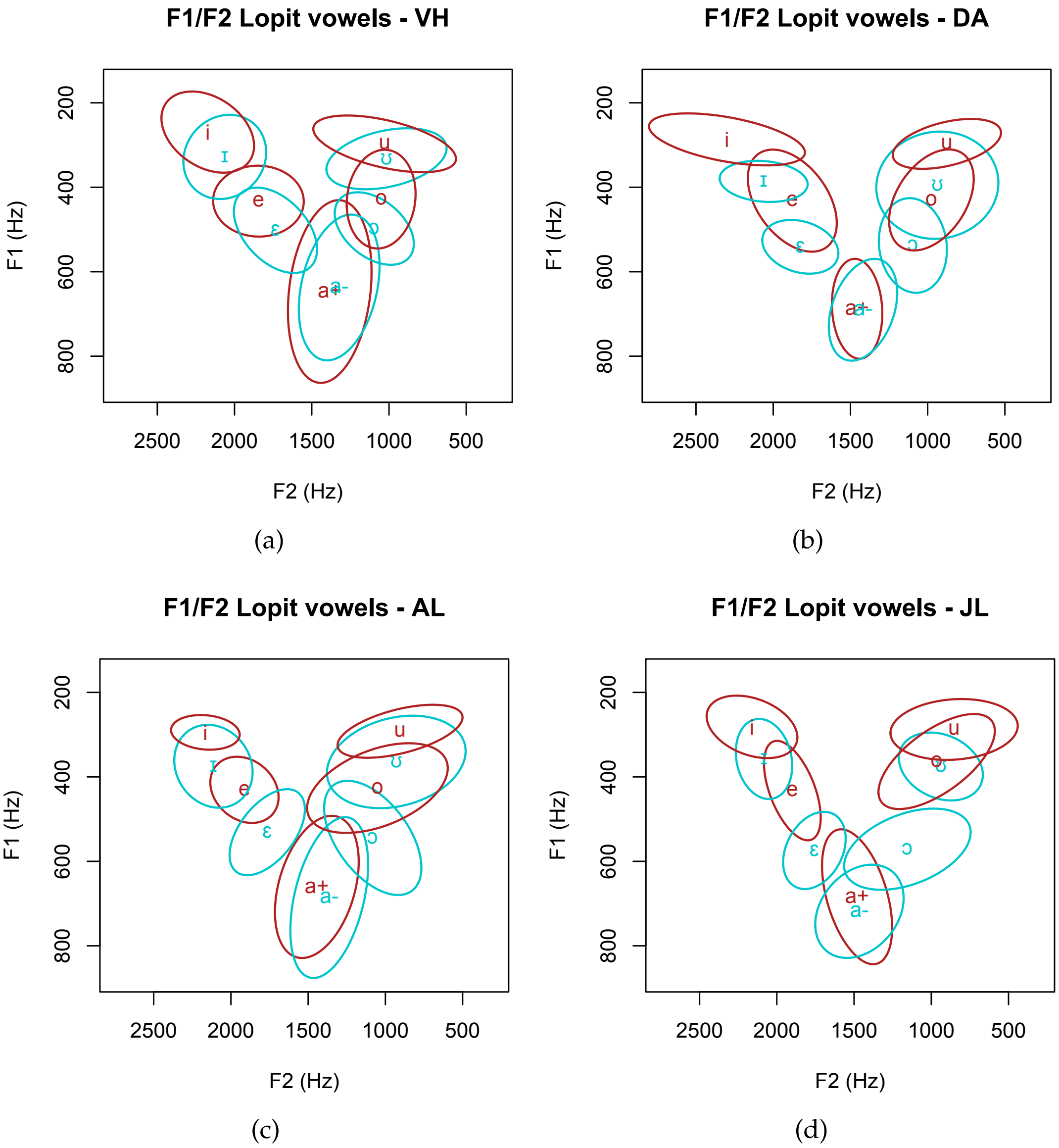


Figure 4.2: *First and second formant frequencies (Hz) at midpoints of Lopit monophthongs, for each participant (95% confidence intervals).*

Table 4.2: *Selected results of statistical comparisons between vowels for F1 values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

F1 comparison	result
/i/ ∼ /ɪ/	***
/e/ ∼ /ɛ/	***
/o/ ∼ /ɔ/	***
/u/ ∼ /ʊ/	***
/a+/ ∼ /a-/	-
/ɪ/ ∼ /e/	***
/ʊ/ ∼ /o/	***

4.5.1.2 F2

In Figure 4.2, it can be seen that among the front vowels, the [+ATR] vowels tend to have slightly greater F2 values than their [-ATR] counterparts. Among the back vowels there are less clear F2 patterns, though some speakers have somewhat lower F2 values for /o/ and /u/ than for /ɔ/ and /ʊ/. The result of the likelihood ratio test for F2 data was significant (χ^2(9, N=1200) = 2273.2, p<0.001), indicating that F2 is affected by vowel category. Selected results of post-hoc tests are presented in Table 4.3. For /i/ and /ɪ/, the difference in F2 is significant, with /i/ having values an estimated 126 ± 29 Hz higher. Similarly, for front vowel /e/ compared to /ɛ/, F2 values are 171 ± 30 Hz higher. Among the back vowels, /o/ and /ɔ/ are also significantly different in terms of F2, with F2 values for /o/ being an estimated 170 ± 33 Hz lower. However, for the close back vowels /u/ and /ʊ/, F2 differences are not significant (p=0.65). For the close/mid pairs, F2 is significantly higher for /ɪ/ compared to /e/, by an estimated 111 ± 29 Hz, but there are no significant differences between /ʊ/ and /o/ (p=0.61). There are also no significant differences between F2 values for /a/ in the [+ATR] environment compared to /a/ in the [-ATR] environment (p=1.00). When the overall ATR category was tested as a main effect, it was also shown to be significant ((χ^2(1, N=1200) = 204.91, p<0.001). The summary of all vowel comparisons in Table D.7 also shows significant F2 differences between other vowel pairs where expected based on the IPA symbols chosen to represent them (in fact, the only comparisons for which F2 differences are not significant are /ʊ/ and /u/, /ʊ/ and /o/, and the tokens of /a/ in each context).

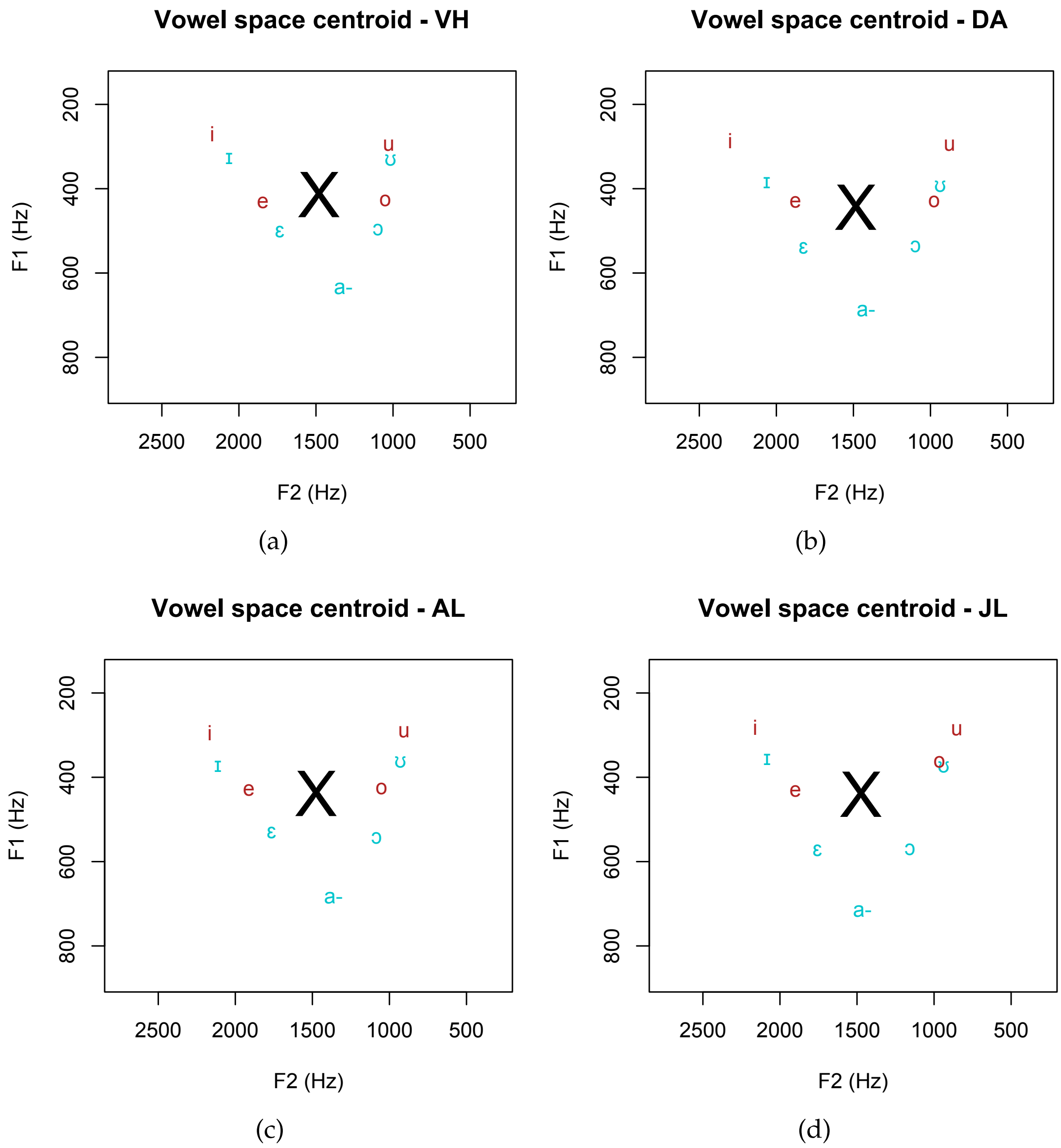


Figure 4.3: *Overall centroid of Lopit vowel space, based on F1/F2 midpoint values (Hz) averaged across vowels. /a/ in the context of [+ATR] vowels is not included here.*

Table 4.3: *Selected results of statistical comparisons between vowels for F2 values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

F2 comparison	result
/i/ ∼ /ɪ/	***
/e/ ∼ /ɛ/	***
/o/ ∼ /ɔ/	***
/u/ ∼ /ʊ/	-
/a+/ ∼ /a-/	-
/ɪ/ ∼ /e/	**
/ʊ/ ∼ /o/	-

4.5.1.3 Euclidean distances

Table 4.4: *Selected results of statistical comparisons between vowels for Euclidean distance values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

Euclidean distance comparison	result
/i/ ∼ /ɪ/	***
/e/ ∼ /ɛ/	***
/o/ ∼ /ɔ/	-
/u/ ∼ /ʊ/	-
/a+/ ∼ /a-/	-
/ɪ/ ∼ /e/	***
/ʊ/ ∼ /o/	***

In Figure 4.3, the overall vowel space centroid is shown for each speaker, based on F1/F2 values averaged across all vowels. /a/ in the context of [+ATR] vowels was not included in determining the centroid; results for F1 and F2 already indicate that this is unlikely to be a distinct phoneme, as hypothesised, and its inclusion would add a bias towards higher F1 values for the overall centroid. To give an indication of the peripherality of different vowels, boxplots of Euclidean distances are presented in Figure 4.4. As noted earlier, these are measures of the distance, in Hz, from the overall centroid of the vowel space to the F1/F2 points for individual vowel tokens. The likelihood ratio test performed for Euclidean distance measures returns a significant result (χ^2(9, N=1200) = 894.81, $p<0.001$), indicating that this measure of peripherality is influenced by vowel category. While the [+ATR] vowels tend to have higher Euclidean distance values than the [-ATR] vowels, placing them further away from the overall centroid of the vowel

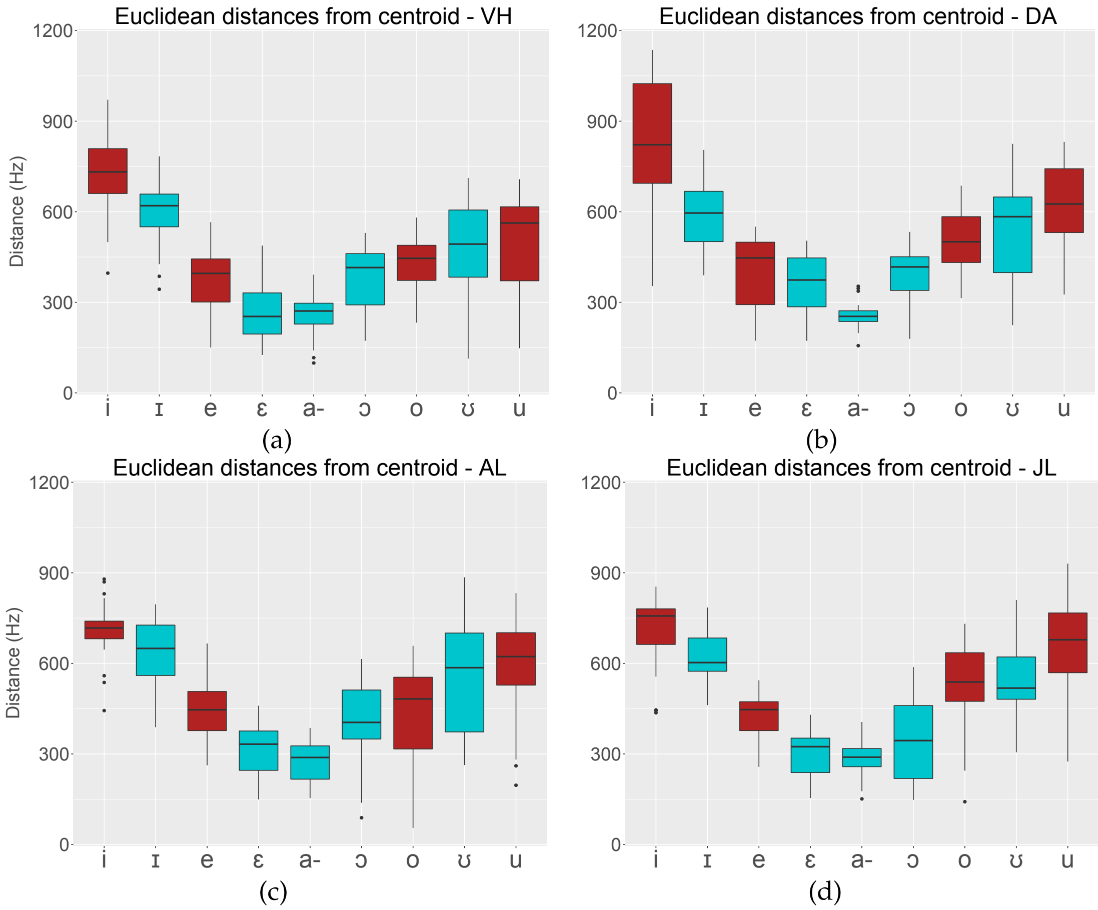


Figure 4.4: *Euclidean distances from the centroid of each speaker's vowel space (Hz), for each vowel. /a/ in the context of [+ATR] vowels is not included here.*

space, the post-hoc test results in Table 4.4 show that this is not significant for all vowel pairs. Values for /i/ are an estimated 138 ± 25 Hz higher than for /ɪ/, and values for /e/ are 155 ± 27 Hz higher than for /ɛ/. However, for /o/ compared to /ɔ/, and /u/ compared to /ʊ/, the respective differences are not significant (p=0.80, p=0.60). For the pair of close/mid front vowels, /ɪ/ has Euclidean distance values an estimated 113 ± 26 Hz higher than those for /e/, and for the close/mid back vowels, /ʊ/ has values an estimated 133 ± 31 Hz higher than those for /o/. There are no significant differences in Euclidean distance between /a/ in the [+ATR] environment compared to /a/ in the [-ATR] environment (p=1.00). When the main effect of ATR category was tested, it was shown to have a significant effect (χ^2(1, N=1200) = 291.91, p<0.001), and post-hoc tests indicate that overall, [+ATR] vowels are significantly more peripheral than [-ATR] vowels, by an estimated 307 ± 18 Hz.

4.5.1.4 F3

Figure 4.5 presents F3 values plotted against F2 values for the four speakers. The result of the likelihood ratio test is significant (χ^2(9, N=1200) = 382.2, p<0.001), suggesting that vowel category does have a greater influence on F3 than other factors, but most significant results are not for the vowel pairs of interest here. For /i/ compared to /ɪ/, F3 values are somewhat higher but not significantly so (p=0.64). For /e/, F3 values are significantly higher than for /ɛ/ by an estimated 108 ± 27 Hz. There are no significant differences between /o/ and /ɔ/ (p=0.97), or between /u/ and /ʊ/ (p=1.00), nor between tokens of /a/ in each of the two environments (p=0.77). Similar results obtain for comparisons between the close/mid pairs; differences do not reach significance for /ɪ/ compared to /e/ (p=0.21), nor do they reach significance for /ʊ/ compared to /o/ (p=0.92). The main effect of ATR category is, however, significant (χ^2(1, N=1200) = 49.094, p<0.001), and points towards [+ATR] vowels having F3 values an estimated 96 ± 15 Hz higher than those for [-ATR] vowels.

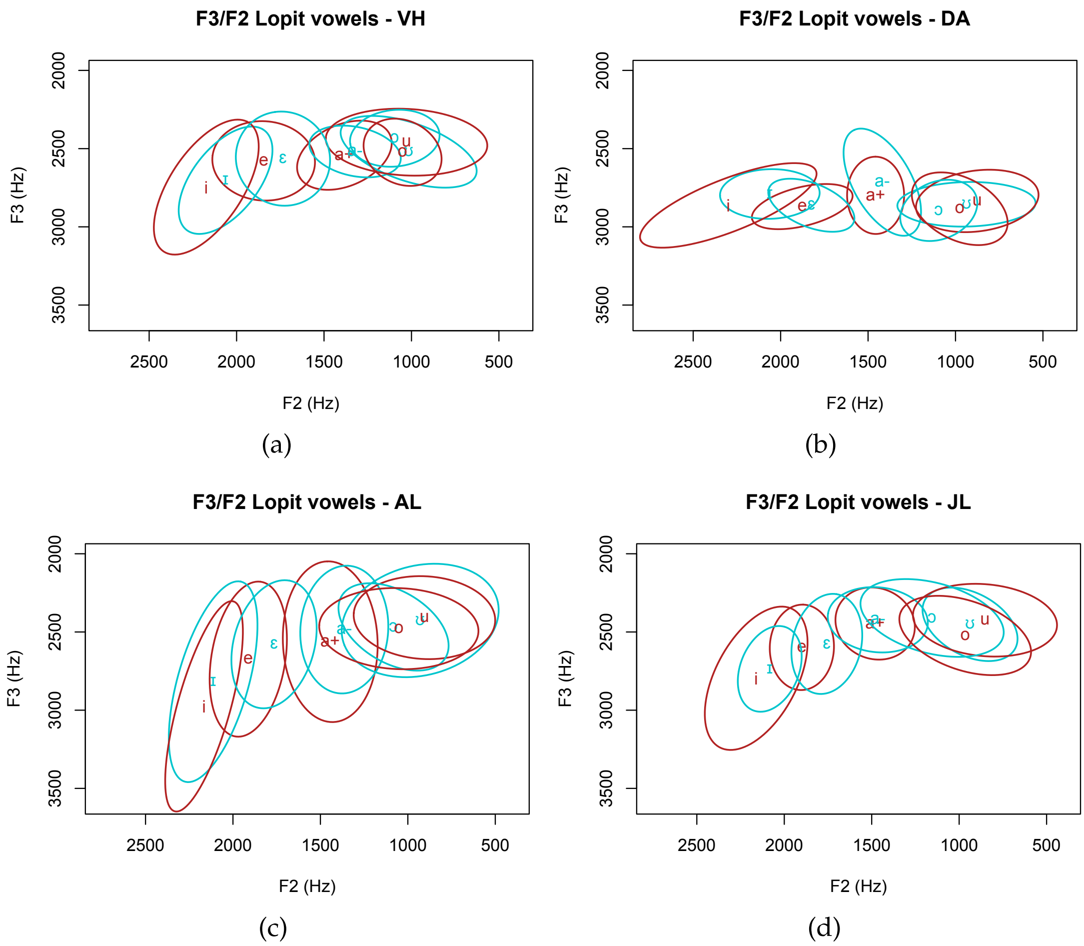


Figure 4.5: *Second and third formant frequencies (Hz) at midpoints of Lopit monophthongs, for each participant (95% confidence intervals).*

Table 4.5: *Selected results of statistical comparisons between vowels for F3 values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

F3 comparison	result
/i/ ∼ /ɪ/	-
/e/ ∼ /ɛ/	**
/o/ ∼ /ɔ/	-
/u/ ∼ /ʊ/	-
/a+/ ∼ /a-/	-
/ɪ/ ∼ /e/	-
/ʊ/ ∼ /o/	-

4.5.2 Duration

Figure 4.6 shows the distribution of duration values for each vowel analysed. For each vowel, there is a great deal of variation, particularly among the non-front vowels. This is not surprising given that the wordlist used to elicit these data includes vowels in words of different lengths (2 and 3 syllables) and different syllable types, and as noted the statistical model for duration comparisons was improved with the inclusion of these variables as random effects. When duration data were submitted to a likelihood ratio test, this gave a significant result ($\chi^2(9, N=1200) = 254.94$, $p<0.001$), showing that vowel category had a significant effect on duration. However, for the specific vowel pairs of interest in the present study, very little of significance emerged from the post-hoc tests; the only notable difference is that /e/ is an estimated 66 $\pm$ 10 ms longer than /ɪ/. No significant duration differences were observed for /i, ɪ/ (p=0.97), /e, ɛ/ (p=0.19), /o, ɔ/ (p=0.87), /u, ʊ/ (p=0.91), /ʊ, o/ (p=1.00), or /a/ tokens in each context (p=1.00).

When the main effect of ATR category on vowel duration was tested, with the same random effects as for individual vowel category, the result was in this case not significant ($\chi^2(1, N=1200) = 0.7345$, $p=0.39$). When the possible effects of word length on the duration of [+ATR] compared to [-ATR] vowels are further inspected, results suggest that the different vowel categories may be differently affected. A likelihood ratio test of the effect of ATR vowel category in different word lengths (with random effects of speaker, word, tone and syllable type) returns a significant result ($\chi^2(3, N=1200) = 37.064$, $p<0.001$), and while there is a general tendency towards higher duration values for vowels in 2-syllable compared to 3-syllable words, post-hoc tests show that these differences are not significant for [+ATR] vowels (p=0.66). However, [-ATR] vowels are significantly longer in 2-syllable compared to 3-syllable words, by an estimated 36 $\pm$ 7 ms.

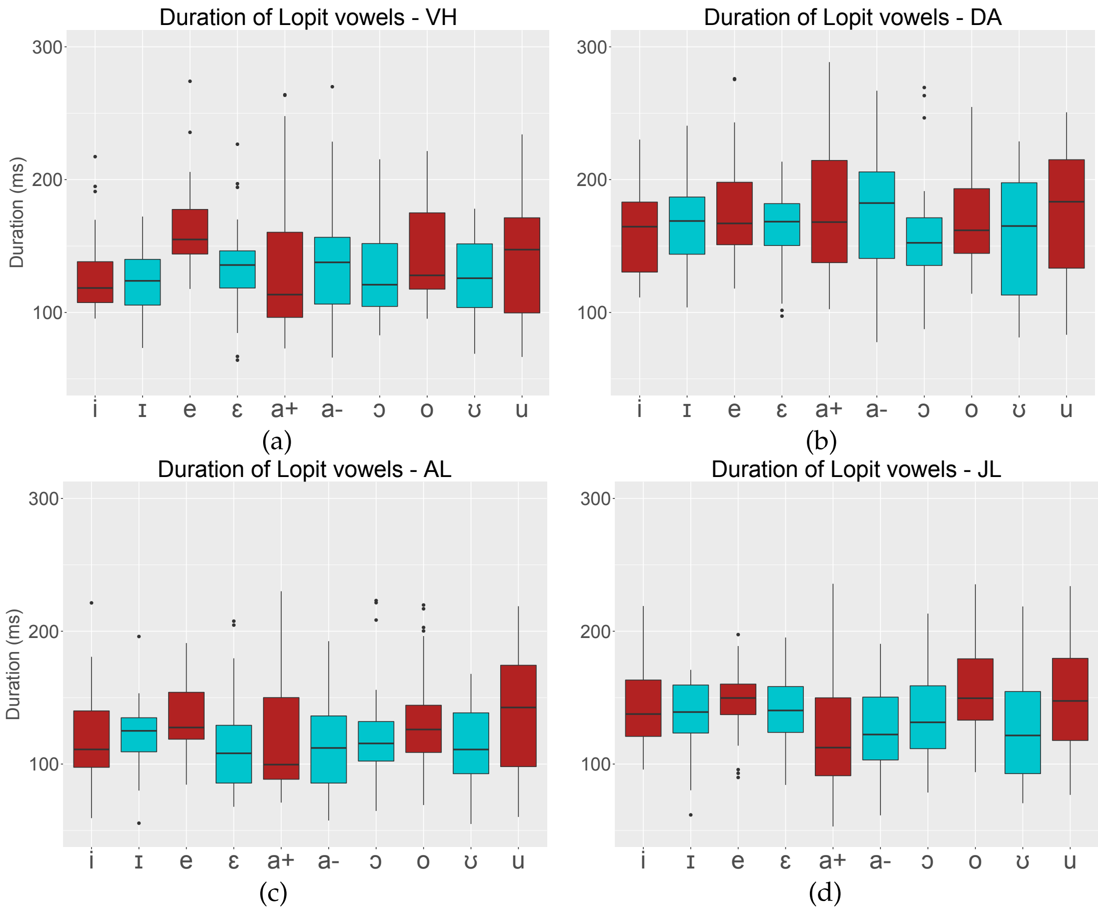


Figure 4.6: *Duration values (ms) of Lopit monophthongs, for each participant.*

Table 4.6: *Selected results of statistical comparisons between vowels for duration values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

Duration comparison	result
/i/ ∼ /ɪ/	-
/e/ ∼ /ɛ/	-
/o/ ∼ /ɔ/	-
/u/ ∼ /ʊ/	-
/a+/ ∼ /a-/	-
/ɪ/ ∼ /e/	***
/ʊ/ ∼ /o/	-

4.5.3 Spectral emphasis

The plotted results for spectral emphasis measures, shown in Figure 4.7, show a great deal of variation. While in some cases there are patterns of lower dB values for closer vowel qualities, including [+ATR] compared to [-ATR] vowels, these are not consistent across vowel pairs or speakers. The likelihood ratio test returns a significant result, indicating that individual vowel category influences spectral emphasis values (χ^2(9, N=480)= 61.605, p<0.001), but as for the duration results, there are almost no differences in spectral emphasis for the vowel pairs which are the focus of this experiment. As shown in Table D.7, significant differences were mostly for the close vowels /i/ and /u/ compared to more open vowels. The trend towards lower spectral emphasis values for /i/ than /ɪ/ approaches significance (p=0.09), but there is little observable difference for /e, ɛ/ (p=0.70), /o, ɔ/ (p=0.60), /u, ʊ/ (p=0.31), /ʊ, o/ (p=0.87), or /a/ tokens in each context (p=0.99). When the data were tested with overall ATR category as the fixed effect, rather than individual vowel category, the likelihood ratio test was again significant (χ^2(1, N=480)= 17.184, p<0.001), and the Tukey's post-hoc test showed that overall, [+ATR] vowels have spectral emphasis values significantly lower than those of [-ATR] vowels, by an estimated 1.8 $\pm$ 0.4 dB. It is worth noting that where the spectral emphasis values were checked with individual ANOVAs for each speaker, the differences were significant for each pair (apart from /a/ tokens) for participant JL, at p<0.001 in each case. While there was no specific hypothesis regarding fundamental frequency in this study, the possibility of any differences by vowel category was checked with this subset of high-toned vowels. The likelihood ratio test returned a significant result (χ^2(9, N=480)= 21.684, p<0.01), but post-hoc tests returned no significant results for the specific vowel pairs of interest in the present study, and a likelihood ratio test with the overall ATR category as main effect approached but did not reach significance (χ^2(1, N=480)= 3.0191, p=0.08).

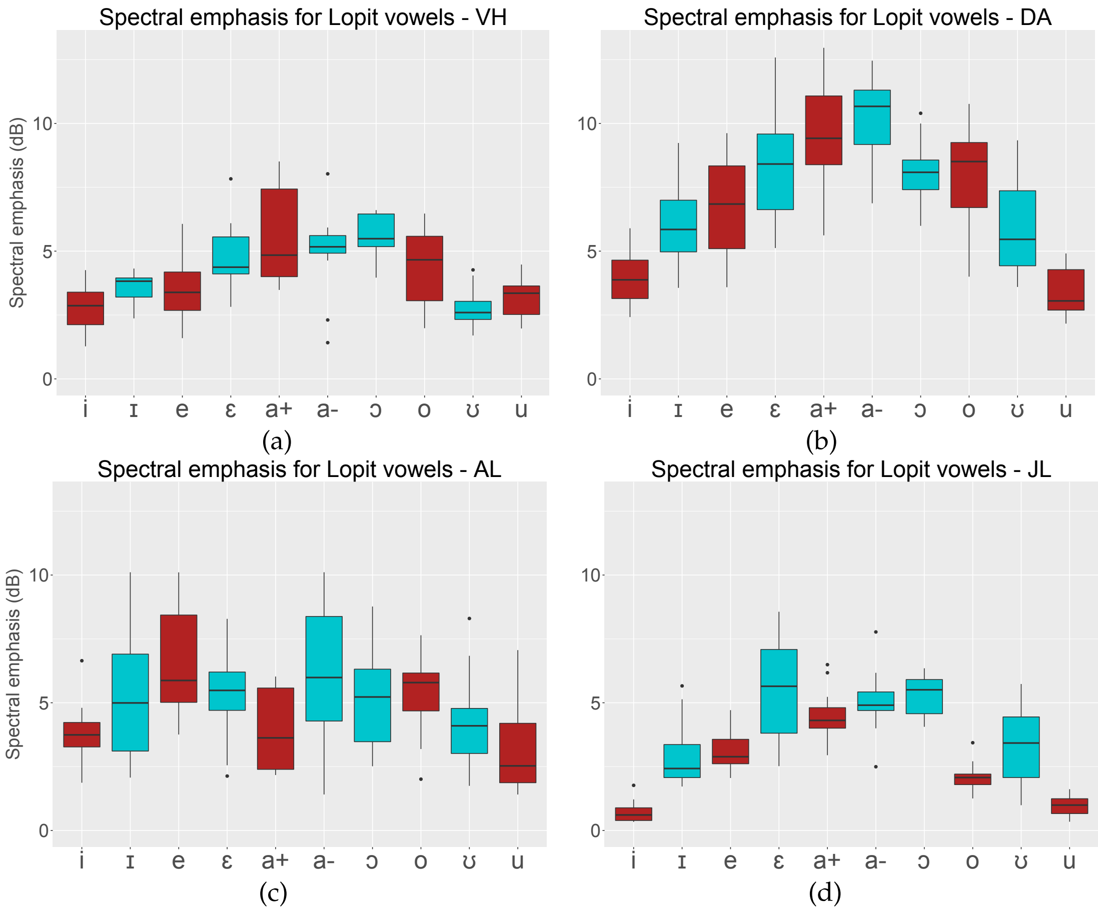


Figure 4.7: *Spectral emphasis values (dB) of Lopit monophthongs, for each participant.*

Table 4.7: *Selected results of statistical comparisons between vowels for spectral emphasis values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

Spectral emphasis comparison	result
/i/ ∼ /ɪ/	-
/e/ ∼ /ɛ/	-
/o/ ∼ /ɔ/	-
/u/ ∼ /ʊ/	-
/a+/ ∼ /a-/	-
/ɪ/ ∼ /e/	-
/ʊ/ ∼ /o/	-

Table 4.8: *Summary of statistical results for other key vowel comparisons, as part of establishing overall vowel space. For the results of all possible comparisons, see Table D.7 (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

Comparison	F_1	F_2	F_3	Euclidean dist.	Duration	Spectral emph.
/i/ ∼ /u/	-	***	***	***	***	-
/ɪ/ ∼ /ʊ/	-	***	***	-	***	-
/e/ ∼ /o/	-	***	***	-	***	-
/ɛ/ ∼ /ɔ/	-	***	-	-	***	-
/a/ ∼ /ɛ/	***	***	-	-	-	-
/a/ ∼ /ɔ/	***	***	-	**	**	-

4.6 Methodology - Articulatory Analyses

4.6.1 Participants

Participants VH and DA (chosen for their availability) took part in the collection of articulatory data, which followed some time after the acoustic study discussed here.

4.6.2 Materials

For the analyses of articulatory data collected with ultrasound tongue imaging, a subset of the wordlist for the acoustic analyses was used, containing two words for each of the vowels of interest (though only one each for /a/ in the environment of [+ATR] vowels compared to /a/ in the environment of [-ATR] vowels). The wordlist was kept short because the collection of ultrasound data can be more tiring for participants, and is also substantially more time-consuming in the set-up and analysis stages than the collection of audio-recorded data alone. The list is shown in Appendix C, in Table C.3 (and is almost identical to the examples given earlier in Table 4.1).

4.6.3 Elicitation and recording procedures

The wordlist items were shown to participants as an orthographic prompt on a computer screen, this time delivered using the software Articulate Assistant Advanced (Articulate Instruments Ltd, 2012). For this study, the prompts were shown as individual words only, rather than in a frame, and this study is therefore based on words produced in isolation.

Each word in the wordlist was shown three times in a row, and the wordlist was repeated three times, in order to record each word nine times and obtain 18 tokens of each vowel of interest (recalling that there were two words representing each vowel). Due to time constraints, it was not possible to record the words with tokens of /a/ for participant DA. In between iterations, participants were also recorded swallowing (with water) in an attempt to additionally collect images of the palate shape, but no reliable palate images were able to be obtained. As the participants produced the wordlist items, ultrasound imaging of lingual gestures took place using the Mind Ray DP6600 ultrasound machine and a 65EC10EA microconvex transducer at 6.5MHz. The transducer has a 120° field of view, and is placed at the underside of the jaw. The probe depth for each participant was set following tests of which depth produced the clearest image of as much of the tongue body as possible, and was 10.8cm for VH and 9.7cm for DA. Images were captured as video using Articulate Assistant Advanced at a variable frame rate of 24fps, and audio-recording took place concurrently. The participants wore a Probe Stabilisation Headset (Articulate Instruments Ltd, 2008), as shown in Figure 4.8, in order to keep the position of the transducer constant, and therefore enable comparisons between different tokens produced.[10]


(a)


(b)

Figure 4.8: *Participants wearing AAA Probe Stabilisation Headset for the collection of data using ultrasound tongue imaging (photos used with permission).*

[10]My sincere thanks to Hywel Stoakes for his invaluable assistance in enabling the collection of these data.

4.6.4 Data processing and analysis

4.6.4.1 Segmentation and labelling

Video files were de-interlaced to 50fps, and synchronisation of audio and video was checked and corrected as necessary using Sony Vegas. Following the same procedures as in 4.4.4.1, audio data were segmented and labelled in Praat using broad phonetic transcription, with additional labelling of the midpoint of each vowel. The video frames corresponding to each of these points were then extracted using Anvil (Kipp, 2012) with reference to the labelled textgrids.

4.6.4.2 Tongue contour tracing

The midpoint frames for each vowel token were imported into EdgeTrak (Li, Kambhamettu & Stone, 2005) for semi-automatic tracing of tongue contours. As described by Li et al. (2005), Edgetrak implements a model which identifies the lower edge of the white bands corresponding to the reflection of ultrasound waves at the tongue's upper surface, based on an assessment of the intensity in local regions of the image. As shown in Figure 4.9, a contour (or 'snake') is generated based on this, which can be hand-corrected, as was required for some tokens. For some frames, image quality was too poor for contour tracing to take place. The final dataset comprised contours from a total of 249 tokens. The traced contours were exported from Edgetrak as a series of XY coordinates, with 100 points for each contour, and a conversion from pixels to cm based on the probe depth setting used for each participant.

4.6.4.3 Statistical tests

The data were compiled and imported to R (R Development Core Team, 2016), and comparisons of the tongue shape, as indicated by the XY coordinates for traced contours, were undertaken using Smoothing Spline Analysis of Variance (SSANOVA) (Gu, 2002; Wang, 2011). The SSANOVA procedure has elsewhere been applied to continuous acoustic data such as formant trajectories (e.g. De Decker & Nycz, 2006; Fruehwald, 2010; Docherty,

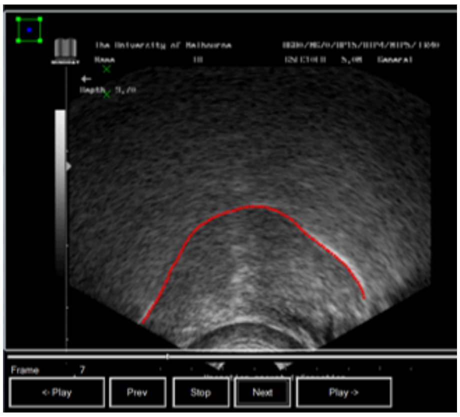


Figure 4.9: *Example of tongue contour tracing in Edgetrak for token of /ɔ/.*

Gonzalez & Mitchell, 2015) and fundamental frequency trajectories (e.g. Moisik, Lin & Esling, 2013; Chuang, Chang & Hsieh, 2013; Yiu, 2014), as well as in articulatory studies of nasal airflow (Stoakes, Fletcher & Butcher, 2016), MRI imaging studies of tongue shape (Barlaz et al., 2015), and ultrasound-based analyses of larynx height (Moisik et al., 2013). In particular, SSANOVA comparisons have been used in a number of ultrasound studies of lingual gestures (e.g. Davidson, 2006; Kochetov, Sreedevi, Kasim & Manjula, 2014; Yamane, Howson & Wei, 2015; Mielke, 2015; Heyne & Derrick, 2015). The procedure returns values for a smoothing spline which would best fit all the data, and for the spline of the interaction (the difference between the best fit and the splines for the main effect, in this case vowel category), so that significant differences in the shapes of static curves, or continuous time-series data, can be identified.

In the present study, this was implemented using the `gss` package in R (Gu, 2013) and a modified version of a script by Mielke (2013). Importantly, in this script the Cartesian coordinates generated by Edgetrak are converted to polar coordinates for the purposes of the SSANOVA. Numerical data expressed in Cartesian coordinates assume a two-dimensional plane with a horizontal axis x perpendicular to a vertical axis y. In the case of XY points derived from video frames collected during mid-sagittal tongue imaging, the x dimension is interpreted as anteriority and the y dimension as height. However, implementations of SSANOVA using Cartesian coordinates are not well-suited to estimating differences in tongue configuration, because the shape of the tongue body more closely approximates an arc than a line parallel to the x axis. Though reasonable results may be obtained for sections of the contour corresponding to the highest point of the tongue, comparisons of tongue root and tongue tip position are significantly affected as the variation is increasingly around a vertical rather than horizontal slope. Polar coordinates instead assume a plane with a central reference origin, and numerical data are expressed as an angular coordinate θ and radial coordinate r. Comparisons of SSANOVA results using data in Cartesian compared to polar coordinates show that polar coordinates are more appropriate and accurate for analyses of tongue configuration (Mielke, 2015; Heyne & Derrick, 2015). Following SSANOVA calculations, splines were plotted according to the main effect using `ggplot2` (Wickham, 2009). Where the splines show no overlap in their 95% confidence intervals, they are considered to be significantly different.

4.7 Results - Articulatory analyses

Figure 4.10 and Figure 4.11 show the SSANOVA results for each pair of vowels for participants DA and VH. For the pairs /i, ɪ/, /e, ɛ/, /o, ɔ/ and /u, ʊ/, differences in lingual shape are apparent. For /i, ɪ/, data for the rearmost portion of the tongue (on the left of each plot), indicate that the tongue position is more anterior for [+ATR] /i/ than for [-ATR] /ɪ/, for both participants. There are also some slight differences in tongue body height for VH, with /i/ having a more raised position. For the mid-front vowels /e/ and /ɛ/, a similar pattern is seen, with the rearmost portion of [+ATR] /e/ having a more anterior tongue position than [-ATR] /ɛ/. For DA, there is also a more raised tongue body for /e/. Among the back vowels, similar observations can be made; for /o, ɔ/, it is [+ATR] /o/ which has a more anterior tongue position, and for DA, also a more raised position. For /u, ʊ/, it is again the [+ATR] vowel, /u/, which shows a more anterior gesture. The curve for /u/ also shows a more raised gesture than for /ʊ/, particularly for DA.

Overall, then, these results suggest that the two speakers consistently use an articulatory gesture which results in a more anterior position of the rear of the tongue for [+ATR] vowels compared to [-ATR] vowels. Differences in both individual physiology and in the extent to which the tongue is captured during imaging mean that it is difficult to be precise about what portion of the tongue the rearmost *imaged* portion corresponds to, and these data do not directly provide information about postures in the lower vocal tract, but these differences in the position of the tongue root may be an effect of overall differences in pharyngeal aperture and laryngeal configuration. The same is not observed in SSANOVA results for the open vowel /a/ produced by VH in the context of [+ATR] vowels compared to [-ATR] vowels, where a [+ATR] counterpart would be expected if it were a salient phonemic or allophonic vowel category in Lopit. As shown in Figure 4.11e, there is clear overlap in the confidence intervals for each set of tokens at both the tongue posterior and the rest of the tongue body, indicating that at least for VH, the articulatory target is the same for /a/ in both contexts, and supporting acoustic results for all four participants that there are not two distinct open vowel qualities.

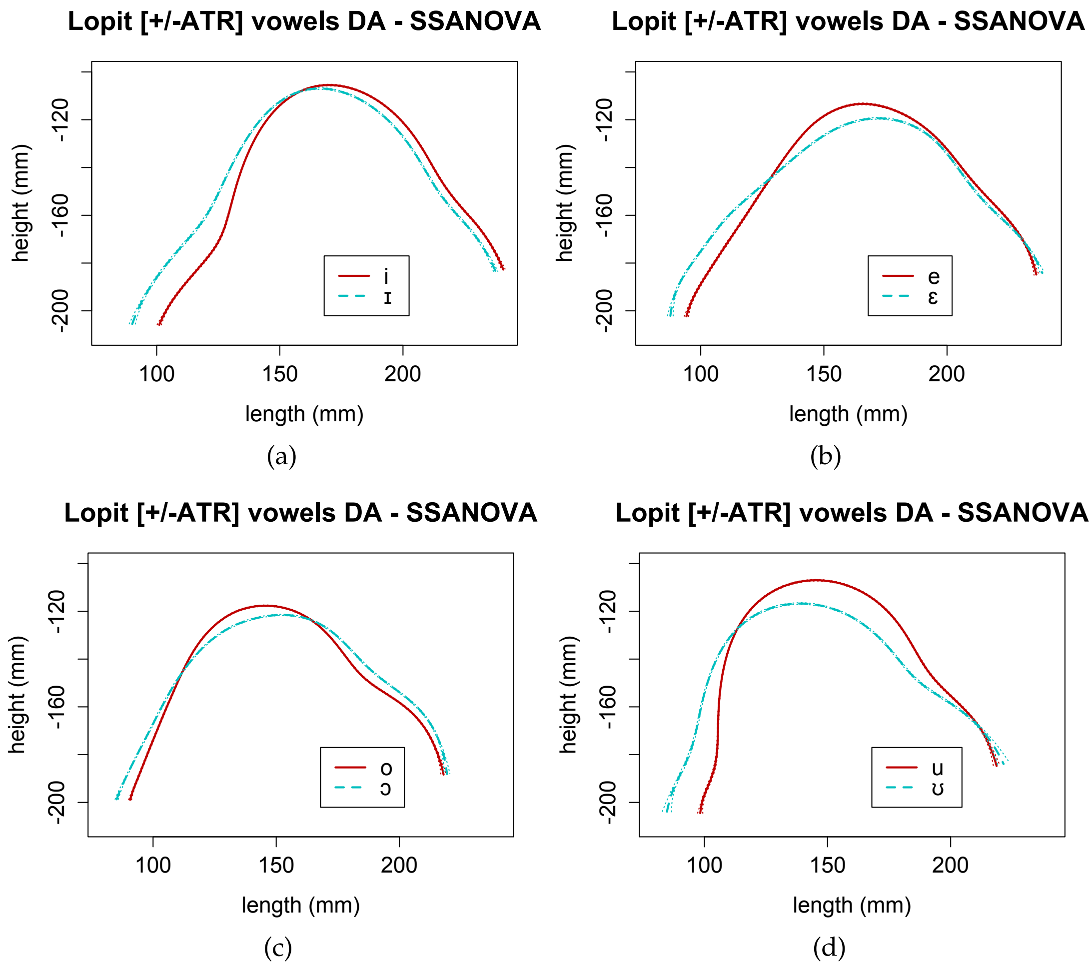


Figure 4.10: *SSANOVA results (mm) for traces of Lopit vowels for participant DA. Tongue root is on the left.*

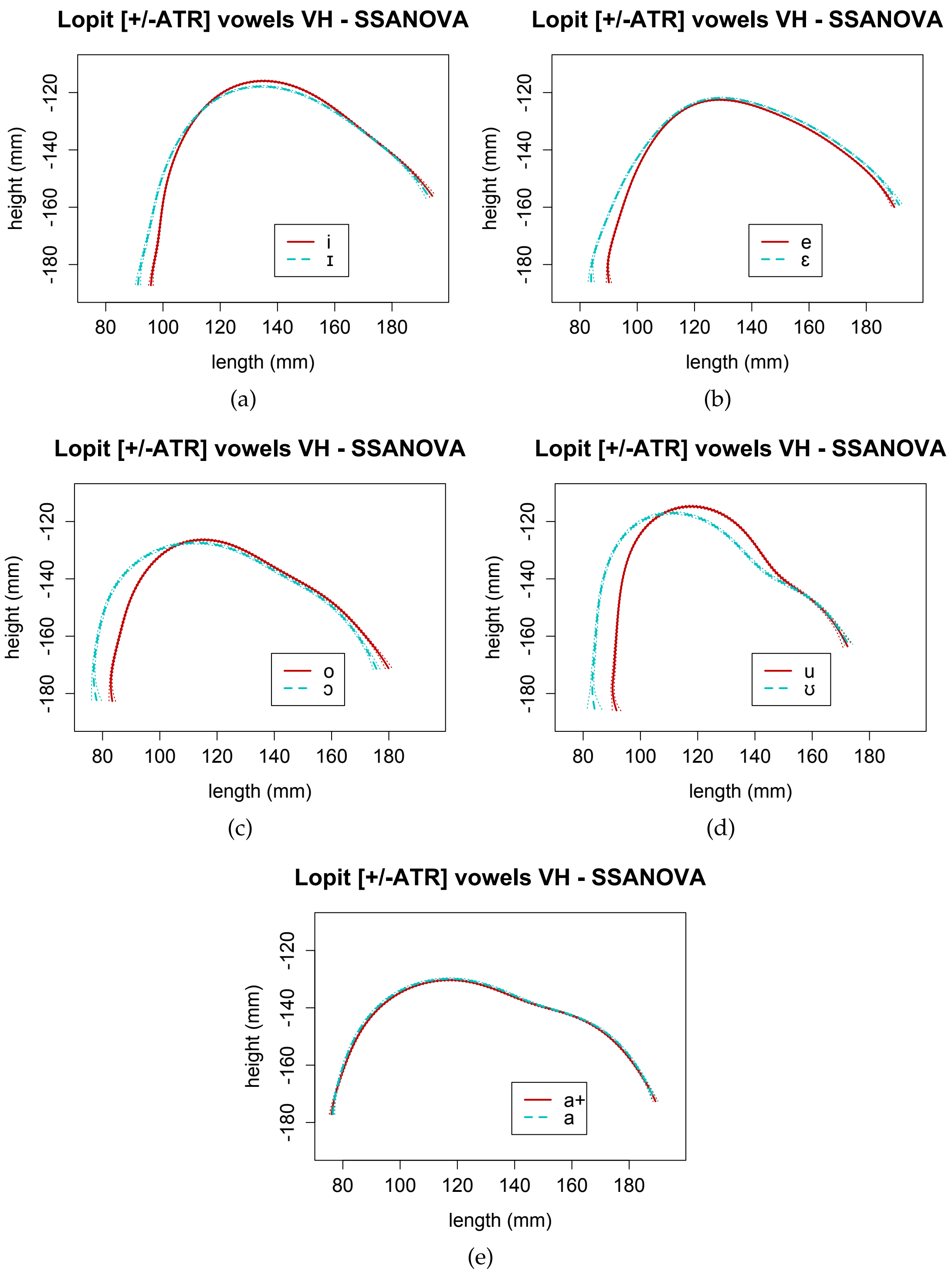


Figure 4.11: *SSANOVA results (mm) for traces of Lopit vowels for participant VH. Tongue root is on the left.*

4.8 Discussion

4.8.1 Acoustic and articulatory correlates of ATR category

The four hypotheses tested in this chapter relate to Research Question 2: "What are the acoustic correlates of vowel contrasts found in Lopit?" and Research Question 3: "What sorts of articulatory mechanisms are involved in producing Lopit vowel contrasts?" Taken together, results provide strong phonetic evidence for the perceived phonological distinction between nine monophthongs, which was proposed in Chapter 3. Plots of the F1/F2 vowel space, as shown in Figure 4.2, give an indication of the differences between them, as do the additional acoustic and articulatory results which follow, and which are summarised for all vowel comparisons in Table D.7. A crucial part of assessing the distinctions in the Lopit vowel space was establishing whether there is evidence for a contrast between vowel pairs of similar height, backness and rounding: /i, ɪ/, /e, ɛ/, /o, ɔ/ and /u, ʊ/. It was suggested in 3.4 that the label [+ATR] could be applied to the former in each pair, and [-ATR] to the latter, based on how these labels are conventionally used to describe the vowel systems of Nilotic languages, but it was noted that the evidence for and correlates of this proposed 'Advanced Tongue Root' distinction require instrumental investigation. The acoustic evidence for the proposed distinction is the focus of the first hypothesis, given in 4.3.

Phonetic results presented in 4.5 clearly support the hypothesis that there is a distinction between the vowels in each pair. Of the acoustic and durational measures, F1 is the most robust indicator of the distinction, and more generally of membership to the [+ATR] compared to the [-ATR] set, with the results of statistical tests revealing substantial and significant differences ranging from 67–126 Hz between /i, e, o, u/ and their harmonic counterparts in the set /ɪ, ɛ, ɔ, ʊ/. F1 values for putative [+ATR] vowels are lower than for the [-ATR] vowels, lending quantitative support to the impressions of closer vowel qualities for this set noted by early authors on languages of the Lotuxo group (Muratori, 1938), and also mentioned in previous work on Lopit (Turner, 2001, p. 40). These results also match the most common finding in previous phonetic studies that F1 is a major correlate of ATR category in many Niger-Congo and Nilo-Saharan languages (e.g.

Lindau & Ladefoged, 1986; Hess, 1992; Fulop et al., 1998; Casali, 2003; Local & Lodge, 2004; Przezdziecki, 2005; Starwalt, 2008), including the Eastern Nilotic languages Ateso (Lindau, 1975) and Maa (Guion et al., 2004), for which F1 differences were significant between all four pairs of vowels. These observations for F1 make sense given that the articulatory gestures proposed to correlate with [+ATR] vowels result in a larger cavity compared to the greater constriction observed for the [-ATR] set, based on aryepiglottic stricture, degree of tongue retraction, larynx height and pharyngeal width (Lindau, 1974, 1976; Tiede, 1996; Edmondson & Esling, 2006) with resonance effects including lowering of the first formant. However, given that similar acoustic effects can be achieved through articulatory adjustments that are primarily lingual rather than laryngeal in origin, such as raising or lowering of the tongue body, the articulatory gesture accompanying the acoustic differences in F1 cannot be straightforwardly assumed, a matter returned to below.

In Lopit, F2 appears to be an additional correlate of ATR category. The [+ATR] vowels in the pairs /i, ɪ/, /e, ɛ/ and /o, ɔ/ are more peripheral in the front-back dimension than the [-ATR] vowels, with differences ranging from 126–171 Hz. However, there are no significant F2 differences for /u/ compared to /ʊ/. When Euclidean distances across the F1/F2 plane are used instead as a measure of peripherality, significant differences in the distance from the centroid of the overall vowel space are found only among the front vowels, with [+ATR] /i/ and /e/ tending to be more peripheral than their [-ATR] counterparts by 138–155 Hz. Previous studies have found some F2 differences between [+ATR] and [-ATR] vowels, though the direction of difference varies across languages and vowel pairs. Though Ladefoged and Maddieson (1996b, pp. 304–305) suggest a general pattern of [+ATR] vowels having higher F2 values than [-ATR] vowels, results from a range of other languages, such as in Starwalt's (2008) analyses of eleven Niger-Congo languages, suggest that patterns for F2 are much more variable. As discussed in 4.2.4, higher F2 values are more common among [+ATR] front vowels, though with some possible exceptions, while back [+ATR] vowels may sometimes show higher F2 values, but sometimes lower F2 values, and sometimes no difference. Findings for Lopit also suggest that F3 is unlikely to have a role in distinguishing vowel pairs, with significant differences observed only for /e, ɛ/. In research by Hess (1987), higher F3 values were only observed for

[+ATR] /i/ and /o/ compared to /ɪ/ and /ɔ/, but for the Tungusic language Even, lower F3 values were observed for all of the vowels characterised as 'retracted' compared to 'advanced', and this was suggested to be related to active pharyngeal constriction. The role of F3 therefore likely depends on language-specific implementations of the articulatory difference between vowel sets purported to have constriction differences, and inclusion of this measure in more acoustic studies of ATR may be enlightening.

Duration appears to have no substantial role in ATR contrasts in Lopit. Though the likelihood ratio test was significant, indicating that individual vowel categories in general affect duration, most significant differences relate to vowels which are more distant from one another in the F1/F2 space, as shown in Table D.7. No significant duration differences were found for harmonic pairs. While more nuanced differences may emerge from later research in which greater control of consonantal and phonotactic factors is possible, it is unlikely that duration provides a cue to the ATR distinction in Lopit. This is not surprising, given that existing literature has not found strong evidence for duration as a reliable correlate of ATR category. Though it has only infrequently been measured in studies of ATR, findings in the existing research discussed in 4.2.4 range from tendencies towards higher duration values for some [+ATR] vowels (e.g. Hess, 1992), or towards lower duration values for some [+ATR] vowels (Przezdziecki, 2005), or show no duration differences at all for pairs of [+ATR] and [-ATR] vowels, for example in Eastern Nilotic Maa (Guion et al., 2004). It has been proposed that in Proto-Eastern Nilotic, the original seven vowel system of Proto-Nilo-Saharan, plus a length distinction, was expanded to nine vowels but with a loss of contrastive length; instead, the short equivalents of /i/, /u/ became the [-ATR] /ɪ, ʊ/ (Ehret, 2001). If this is the case, some duration differences among the close vowels would not be unexpected. However, as for Maa, no duration differences were observed for harmonic pairs in Lopit. This is, however, interesting in itself, given the strong associations between 'tense' vowel qualities (in the Germanic sense) and long vowel durations crosslinguistically. Early discussions of African vowel systems grappled with whether they could be characterised as 'tense' and 'lax' in the same way as for vowels in many European languages, based on auditory impressions of similarities (Jakobson & Halle, 1962). Though evidence from articulatory studies has shown that the articulatory gestures involved for example in the Germanic language English compared to the Niger-Congo language Akan differ (Tiede, 1996), the general lack of duration difference for [+ATR] and [-ATR] vowels is further evidence that strategies for differentiating vowels are not the same for ATR vowel systems as for these 'tense'/'lax' vowel systems.

In Lopit, there was also no consistent pattern of differences in phonation type, as evidenced by spectral emphasis measures. As for duration, while the likelihood ratio test returned a significant result, significant differences between pairs generally relate to vowels which are further from one another in the F1/F2 space, as can be seen in the summary in Table D.7. No significant differences were observed for individual harmonic pairs. When the overall ATR category was treated as a main effect, a small but significant difference of an estimated 1.8 dB was observed for [+ATR] vowels compared to [-ATR] vowels, but given the lack of specific differences for the pairs of interest, it is unlikely to be used as a substantial cue, and is most likely primarily a resonance effect. In analyses of a similar sort in Maa, results suggest that phonation or voice quality may have a somewhat greater role; measures of spectral slope differed for /e, ɛ/ and for /u, ʊ/, and electroglottographic results show Contact Quotient differences between the vowels in all pairs (Guion et al., 2004). The different findings for the two languages are not particularly unexpected; the literature on Nilo-Saharan and Niger-Congo languages contains many impressionistic remarks of phonatory and voice quality differences for [+ATR] compared to [-ATR] vowels (though none previously for Lopit), but the acoustic findings across languages have failed to converge on a consistent pattern. It seems that phonation only sometimes serves as an additional correlate to ATR distinctions, likely resulting from language-specific differences in glottal and supraglottal gestures (and where it has been found as a correlate, its perceptual salience has not been established). However, other voice quality differences may be present to some extent, and as noted in 2.3.3, it is also possible that the use of these cues varies for speakers of different varieties of a language, or for different individuals speaking the same variety. It is worth continuing to examine patterns for acoustic measures of this sort in ongoing research on Lopit and other Nilotic languages.

The robust findings for F1 suggest that there is an articulatory difference between

[+ATR] and [-ATR] vowels in Lopit. This was the focus of the second hypothesis put forward in 4.3. It was proposed that the two sets of vowels would exhibit gestural differences which result in a more anterior tongue root position for the [+ATR] compared to the [-ATR] set, rather than differences primarily relating to tongue body height. As discussed in 4.7, analyses of tongue contours collected using mid-sagittal ultrasound imaging provide good evidence that this is indeed the case. SSANOVA results based on traces of the tongue body from ultrasound frames corresponding to vowel midpoints indicate a more anterior tongue root position for each [+ATR] vowel compared to a more retracted position for its [-ATR] counterpart, for both participants in the articulatory study, as shown in Figure 4.10 and Figure 4.11. For some vowels, there are additional differences in tongue shape, and differences between the two participants can also be observed, but the gestural difference in the region of the tongue root appears to be consistent across vowel pairs. In cineradiographic, MRI and more recent laryngoscopic studies of vowel production in other African languages (e.g. Lindau, 1979; Tiede, 1996, Edmondson et al., 2007), there is evidence that a more anterior tongue position for [+ATR] vowels co-occurs with an open epilaryngeal space and a neutral or probably lowered larynx position, contributing to the larger resonant cavity and resulting effects on the first formant. In comparison, the more retracted tongue position observed for vowels in the [-ATR] set likely occurs with aryepiglottic constriction and a more raised larynx position, and perhaps some amount of pharyngeal narrowing, leading to a reduced supraglottal space. Though typical uses of mid-sagittal ultrasound only permit a glimpse at the articulatory strategies used in vowel production, it is possible that similar co-occurrences are also present in Lopit. However, the lack of any consistent auditory or acoustic evidence of phonation differences suggests that these articulatory postures are not accompanied by ventricular-fold vibratory activity or changes to the glottal state for one set compared to another, which would be expected to have a more salient phonatory effect.

Previous findings for Eastern Nilotic Ateso indicate that, while there are differences in tongue root position for [+ATR] compared to [-ATR] vowels, differences in tongue height are the main articulatory correlate (Lindau et al., 1972), and findings for Western Nilotic Dholuo indicate that adjustments to both tongue body height and tongue root advancement are differently involved for different vowels, and that speakers vary in the extent to which they draw on a given articulatory mechanism in order to produce the contrasts (Jacobson, 1978). Given this, there is clearly scope for more detailed investigations of vowel articulation in Lopit and other Nilo-Saharan languages using a range of techniques, and with larger groups of speakers; for [ATR] contrasts and similar phenomena there is not yet a good understanding of to what extent speakers may use different articulatory strategies to achieve similar acoustic effects. Based on the present results for two speakers of Lopit, it is reasonable to suggest that the F1 differences which separate vowels in the pairs /i, ɪ/, /e, ɛ/, /o, ɔ/ and /u, ʊ/ are primarily attributable to gestures which lead to differences in the position of the tongue root rather than the tongue body, or at least that the effect on the tongue root is of greater magnitude, but it would also not be surprising if further research showed individual or dialectal variation. While articulatory studies typically involve small numbers of participants, most acoustic analyses of [ATR] contrasts have also involved small numbers of participants, so the possibilities for acoustic variability are also not well understood. Virtually no work has explored the perception of [ATR] distinctions, and this is also an area in which more work is much needed. While F1 is likely to be a major perceptual cue, the role of various secondary correlates which have been identified in different languages is unclear. In sum, these analyses of Lopit vowel production indicate F1 is the primary acoustic correlate of ATR category, strongly supported by F2; only slight tendencies are seen in terms of spectral emphasis, and duration and F3 do not appear to show meaningful differences. Ultrasound tongue imaging points to tongue root position, driven by the articulatory configuration of the lower vocal tract, as a strong contender for the gestural correlate of [+ATR] vowels.

4.8.2 Acoustic characteristics of the close-mid vowels

In addition to examining differences between [-ATR] vowels and their [+ATR] counterparts, this study also compared [-ATR] close vowels /ɪ/ and /ʊ/ to [+ATR] mid vowels /e/ and /o/, respectively, as part of establishing key contrasts in the Lopit monophthong inventory. The third hypothesis put forward in 4.3 proposed that the pairs of close/mid vowels would be phonetically distinct, despite sharing similar formant characteristics and, from many impressionistic remarks and some acoustic evidence in the literature (discussed in 4.2.4), not always being reliably differentiated in African languages with similar vowel inventories. Results presented in 4.5 show that there is clearly a contrast between /ɪ, e/ and between /ʊ, o/, and the correlates of the contrast are similar to those used to distinguish vowels in harmonic pairs. Across the data, F1 differences in the pairs are significant, with /ɪ/ and /ʊ/ having lower F1 values than /e/ and /o/. In both cases the estimated difference is 50 Hz, which is smaller than the 67–126 Hz differences observed for harmonic pairs, but likely salient. In addition, F2 differences for /ɪ, e/ are significant, with /ɪ/ having having higher F2 values than /e/. While there were no significant F2 differences for /ʊ, o/, measures of Euclidean distance, based on F1 and F2 data, indicate that /ɪ/ and /ʊ/ are significantly more peripheral than /e/ and /o/ respectively. There were no significant F3 differences across the present data for /ɪ, e/ and /ʊ, o/. As well as formant differences, duration correlates with vowel type for /ɪ, e/ in Lopit, with /e/ having significantly higher duration values than /ɪ/.

Though the findings for Lopit seem more consistent, they are somewhat similar to findings for Maa (Guion et al., 2004); in Maa, while F1 does have a role in distinguishing /ɪ, e/, it is only found for two out of five speakers in individual tests, and F1 also has a role in distinguishing /ʊ, o/ but this is significant for only three of the five speakers. F2 does not show significant differences across the data for these pairs in Maa; only one speaker shows a significantly higher F2 value for /ɪ/ than /e/, and none show significant F2 differences between /ʊ/ and /o/. It seems, then, that similar formant patterns are being used in the two languages, but more consistently among the Lopit speakers than the Maa speakers. This may well be related to dialectal variation; in the current experiment, all four Lopit speakers who participated are from the same dialect area of Lopit, and are also part of the same small community group whose members share many family connections. Maa speakers collaborating with Guion et al. (2004) were from three different areas of southern Kenya. The two Maa speakers who use F1 to distinguish both the [-ATR] close vowels and [+ATR] mid vowels were from the same region in Kenya. For another two speakers, spectral slope differences appear to be the acoustic correlate distinguishing /ɪ/ and /e/, and these two speakers came from the same region (different to that of the first two). In Maa, duration was the most robust correlate of the difference between /ʊ/ and /o/, with production data for five speakers showing significantly higher duration values for /o/ compared to /ʊ/.

In Lopit, then, the pair /o, ʊ/ are distinguished by F1 and F2, while in Maa, duration is the main correlate, with F1 used to a lesser extent. For /ɪ, e/ in Lopit there is also clear separation by F1, F2, and to a lesser extent by duration, while for Maa, these vowels are not consistently distinguished; while most speakers (four out of five) do show a distinction between the vowels on some measure, they vary in how they achieve this distinction. Guion et al. (2004) suggest that the lack of reliable contrast between these vowels in Maa may lead to their eventual merger. As noted in the previous section, Ehret (2001) argues that /ɪ/ and /ʊ/ developed from the short versions of /i/ and /u/ as Proto-Eastern Nilotic repurposed a length distinction as an ATR contrast. If this historical development is correct and /ɪ, ʊ/ are reflexes of short /i, u/, it would not be surprising to see a tendency for these vowels to have shorter durations than /e, o/; they may have retained durational properties that enable them to remain distinct from vowels with similar formant structures. However, this is highly speculative, and for the present study of Lopit vowels, it can only be said that duration may be a minor supporting cue to the distinction between at least /ɪ/ and /e/, and possibly between /ʊ/ and /o/, but that these vowels are in general well distinguished by formant information alone.

It is worth noting that the functional load of distinctions between /ɪ, ʊ/ and /e, o/ may well be quite low in cases where they are attested as part of a vowel inventory with an [ATR] distinction, and the crosslinguistic variation in how they are realised (or perceived to be realised by non-native ears) is perhaps not unusual. As noted for Lopit in 3.4, and the general overviews of [ATR] phonology in 2.3.1 and 4.2.1, the processes of vowel harmony which are typically described alongside [ATR] contrasts mean that very generally, words tend to have vowels which are either all [+ATR] or [-ATR], though this is mediated by various language-specific factors. [+ATR] vowels such as /e, o/ are therefore unlikely to occur in similar vowel contexts to [-ATR] vowels such as /ɪ, ʊ/, and where [ATR] harmony operates, cues to vowel identity would also be provided by neighbouring vowels. Furthermore, as shown by Starwalt (2008) in a crosslinguistic analysis of vowel production in eleven Niger-Congo languages, the phonetic details of vowels transcribed as /ɪ, e, ʊ, o/ are likely to interact with language-specific factors such as the size of the overall vowel inventory, and speaker-specific factors such as which strategies are being primarily used to distinguish harmonic pairs, particularly /i, ɪ/ and /u, ʊ/. Acoustic data show that one language's /ɪ/ may be equivalent to another language's /e/, and further underscore the need to integrate both phonetic and phonological analyses in analyses of ATR systems, and to be particularly attentive to these close/mid pairs, for which impressionistic transcription has been more fallible than for other distinctions within the systems (Casali, 2008).

4.8.3 One or two open vowels?

Another crucial matter in establishing the Lopit monophthong inventory is assessing whether there is evidence for just one open vowel, /a/, which was classed as a [-ATR] based on phonological evidence, or whether this vowel has a [+ATR] counterpart of a different quality, a matter of some uncertainty in earlier work on Lopit and closely-related languages (as discussed in 4.2.2). This was the focus of the fourth hypothesis presented in 4.3, and it was proposed that the phonetic evidence would indicate one rather than two distinct 'open' vowels. Comparisons of acoustic results for tokens of /a/ in the [+ATR] environment and /a/ in the [-ATR] environment (where the influence of vowel harmony processes should trigger a change in vowel quality), presented in 4.5, indicate that there is no evidence for two distinct open vowels in Lopit. Across the data, no significant differences in F1, F2, F3, duration or spectral emphasis were found when comparing tokens of /a/ in each context. Though articulatory data for /a/ are only available for one participant, the tongue contours from ultrasound imaging of /a/ in each context provide good supporting evidence for the lack of contrast; the contours resulting from SSANOVA comparisons of /a/ in the [+ATR] context and the [-ATR] context directly overlap, as shown in Figure 4.11e, and there is no sign of two distinct gestures. From the combined acoustic and articulatory results, then, it can confidently be stated that the Lopit vowel system includes only one open vowel, /a/, which has no harmonic counterpart, and which can therefore occur with both [+ATR] and [-ATR] vowels as described in Chapter 3.

Although a ten-vowel system with two open vowels has been reconstructed for Proto-Eastern Nilotic (Vossen, 1982), the findings pointing towards only one open vowel in Lopit are not unexpected, not just because of the hesitancy with which previous authors Vossen (1982, p. 192) and Turner (2001, pp. 40–41) suggest a distinction, but also because nine-vowel rather than ten-vowel systems are most common in languages with an [ATR] contrast (Casali, 2008). [+ATR] counterparts to /a/ are suggested to be particularly vulnerable to sound change and neutralisation across Niger-Congo and Nilo-Saharan languages, frequently merging with front and/or back mid vowels (R. M. R. Hall & Creider, 1998). As shown in the overview in 2.3.2, nine-vowel systems are also most typical of the non-Bari Eastern Nilotic languages. Findings for /a/ in Lopit are similar to phonetic results reported for Maa, also a non-Bari Eastern Nilotic language. Guion et al. (2004) find that in a comparison of /a/ occurring in the environment of both [+ATR] and [-ATR] vowels, there are no significant differences in F1, F2, or duration between tokens in the two contexts (F3 was not studied). However, they do observe some non-significant differences in spectral slope, with /a/ in the [+ATR] context tending to have slightly steeper spectral slopes, and an electroglottographic study of data for one Maa speaker also shows significantly lower closure quotients for /a/ in the [+ATR] context. These findings suggest a somewhat more breathy voice quality for /a/ in the context of [+ATR] vowels, which the authors attribute to coarticulatory effects given that for all [+ATR] vowels significantly lower closure quotients were observed.

For languages in the Bari sub-family of Eastern Nilotic which are attested to have a 10-vowel system instead, the available phonological and limited phonetic evidence suggests that where a [+ATR] counterpart to [-ATR] /a/ is attested, is has a markedly different quality to /a/. For example, for Kuku, the two 'open' vowels are transcribed as [-ATR] /a/ and [+ATR] /ɨ/ (Cohen, 2000, p. 7), and for Bari, they are represented as /a/ and /ö/, with the latter non-IPA symbol described as representing an unrounded central vowel which is close or mid (Spagnolo, 1933, p. 4; B. L. Hall & Yokwe, 1981, p. 55; R. M. R. Hall & Creider, 1998, p. 48). Instrumental explorations, though limited, have provided supporting evidence for such a contrast; preliminary data for Kuku show that [+ATR] /ɨ/ has substantially lower F1 values than [-ATR] /a/, corroborating impressions of a much closer vowel quality for /ɨ/ (R. M. R. Hall & Creider, 1998, pp. 48–49) (though likely better represented as close-mid /ɘ/). Similar differences according to F1 are observed for [-ATR] /a/ and [+ATR] /ʌ/ in the 10-vowel system of Western Nilotic Shilluk (Remijsen et al., 2011), and similarly close counterparts to an open vowel have been noted in structurally similar systems further afield, for example /ɯ/ in Tibeto-Burman Nuoso Yi (Edmondson, Esling & Ziwo, 2017). In other cases the difference may hinge at least in part on a more fronted quality for the [+ATR] counterpart to a [-ATR] vowel, as suggested by phonetic data for Western Nilotic Lango (Noonan, 1992, p. 26), or similarly for the non-constricted vs. constricted contrasts in Somali (Edmondson, Esling & Harris, 2004; Kimper, Bennett, Green & Yu, in press). Results of this sort suggest that where there is a distinction between two 'open' vowels in a language with an [ATR] (or similar) system, there is likely to be an audible difference in vowel quality. This is not surprising; given that open, non-front vowels are inherently susceptible to increasing degrees of constriction in the lower vocal tract (Esling, 2005), a less constricted counterpart a vowel such as /a/ likely requires adjustments to the gestures in both the upper and lower parts of the vocal tract of sufficient magnitude to jointly maintain an acoustic distinction. Therefore, for other languages in the Lotuxo family and elsewhere in Eastern Nilotic where the presence of two distinct open vowels is at the very least difficult to detect, if not somewhat doubtful, it seems likely that phonetic data will point to only one open vowel, as in the present data for Lopit. Quantitative investigation of this matter in other Eastern Nilotic languages would be a useful avenue of further research, and better clarify current understandings of the relationship between vowel systems across Nilotic languages (Dimmendaal, 1988).

4.9 Chapter Summary

This chapter has investigated four hypotheses relating to Research Question 2, "What are the acoustic correlates of vowel contrasts found in Lopit?" and Research Question 3, "What sorts of articulatory mechanisms are involved in producing Lopit vowel contrasts?". Results provide strong evidence for an inventory of 9 monophthongs used by the Lopit participants in this study, and specific evidence for the hypotheses targeting key contrasts. It has been demonstrated that there are robust and consistent phonetic differences for vowels in the pairs /i, ɪ/, /e, ɛ/, /o, ɔ/ and /u, ʊ/, for which the label [+ATR] was suggested for the former in each pair, and [-ATR] for the latter. F1 is the primary acoustic correlate of [ATR] category, with significantly lower values observed for vowels in the [+ATR] set. F2 is a supporting correlate, while only minor differences were found for spectral emphasis, and none for duration. Examination of the lingual gestures used by two speakers in the production of Lopit vowels during ultrasound tongue imaging reveals a more anterior tongue root position for the [+ATR] compared to the [-ATR] set, rather than substantial differences in tongue body height. Based on this, it is suggested that the differences in F1 are likely achieved by articulatory postures which result in a larger resonant cavity for the [+ATR] set, likely including an open epilaryngeal space and a neutral or probably lowered larynx in addition to the observably anterior tongue position, compared to an overall more constricted articulation for the [-ATR] set, likely including aryepiglottic sphinctering and a more raised larynx in addition to the differences in tongue position. The acoustic and articulatory results also verify the presence of one rather than two open vowels in the Lopit vowel inventory, with no observable distinctions found according to any measures for tokens of /a/ occurring in the [+ATR] compared to [-ATR] context. In addition, the distinction between [-ATR] close vowels /ɪ, ʊ/ and [+ATR] mid vowels /e, o/ was found to be reliably indicated by differences in F1, and some supporting correlates, despite these often being reported by linguists as difficult to perceive, and not always acoustically distinct, in the wider literature on African vowel systems. Results presented in this chapter provide the first phonetic data on the Lopit vowel system, and support phonological analyses put forward in Chapter 3. They contribute to the typological discussions surrounding [ATR] as a phonological feature, while also illustrating that many of the questions and debates about [ATR] and similar phenomena require more empirical data across languages (and larger groups of speakers), using a range of instrumental techniques, in order to productively progress. In the following chapter, Chapter 5, I turn from the vowel system to selected phenomena of the consonant system, and investigate the phonetic evidence for the proposed contrast between singleton and geminate labial-velar glides.

Chapter 5

Durational and Acoustic Characteristics of Lopit Glides

5.1 Introduction

In the preceding chapter, Chapter 4, the acoustic and articulatory characteristics of Lopit vowels were discussed in detail. Results presented therein shed light on the number of monophthongal contrasts, for which there were inconsistent findings across the limited available literature, and the phonetic nature of the contrasts, which had not previously been examined. A 9-vowel inventory with an 'Advanced Tongue Root' contrast was established, with F1 as the primary acoustic correlate to the ATR distinction. In this chapter, I turn to a discussion of geminate consonants, with a focus on the proposed contrast between singleton glides /w, j/ and geminate glides /wː, jː/, which was noted in Chapter 2 and Chapter 3 as a particularly interesting and intriguing characteristic of the Lopit segmental inventory. This investigation pertains to RQ4, "What are the phonetic characteristics of contrastive glides in Lopit?". Selected findings relating to this question have also been discussed in Billington (2016).

In Chapter 3, I presented an overview of Lopit segmental and tonal contrasts, including phonological evidence for a contrast between singleton and geminate consonants (3.3.4). Of particular interest is the nature of the consonants involved in this contrast; among stops, nasals, and liquids, the contrast occurs primarily at the alveolar place of articulation, and for some consonant types is only used in a limited way (with /tː/ compared to /t/ being a notable exception). However, a contrast of this type is also present for labial-velar and palatal glides, which are, crosslinguistically, among the least common segment types to exhibit length-based contrasts, as noted in 2.2.4 and discussed further below. Impressionistically, proposed singleton compared to geminate glides in Lopit seem to differ in length, but this has not previously been tested. There are also indications from my own impressions, and those of other commentators, that other cues to the contrast may be present, both in Lopit and in related languages with similar proposed segments. The aim of this chapter is to investigate the acoustic characteristics of glides in Lopit, with a view to establishing whether there is indeed a contrast between proposed singleton and geminate labial-velar and palatal glides, and to examine the phonetic nature of any such contrast. The terms 'singleton' and 'geminate' have been used thus far given the impressions of length differences, and duration is therefore a measure of particular interest in this experiment. Formant and intensity measures are also included, in order to provide a more detailed description of glide categories and explore possible additional correlates. Given that length contrasts among glides are typologically unusual, and have been subject to very little phonetic research, these results will likely also be of wider interest.

I begin by drawing together relevant phonological and typological points from previous chapters in 5.2, together with supplementary information on the phonetics of glides and geminates crosslinguistically, to demonstrate the motivations for and approach to this experiment. Hypotheses regarding Lopit glides are put forward in 5.3, and the methodology is explained in 5.4. Results are then presented in 5.5 according to each measure investigated, and discussion of these in relation to each hypothesis follows in 5.6.

5.2 Background

5.2.1 Phonetic properties of glides

As a class of sounds, glides[1] are considered to be approximants which are particularly vowel-like in their characteristics; for [j] and [w], by far the most common glides occur-

[1] Also referred to as semivowels, vocalic approximants, frictionless continuants, and other labels in the literature, sometimes interchangeably, though sometimes with slight differences in meaning.

ring in the world's languages (Ladefoged & Maddieson, 1996b, p. 322), the tongue and upper articulators form a constriction which is narrow, but not sufficiently narrow so as to introduce turbulence, or lead to acoustic discontinuity and a significant pressure drop (e.g. Stevens, 2000, 2002). Transitions between vowels and adjacent glides are longer, and less abrupt, than between vowels and stops (Walsh & Diehl, 1991). Glide segments have much in common with close vowels [i] and [u], respectively; both [j] and [i] involve a constriction in the palatal region of the vocal tract, and are realised with low first formant frequencies and high second formant frequencies, while [w] and [u] are produced with a constriction in the velar region and additional lip rounding, and both the first and second formant frequencies are low and relatively close together (Sun, 1996; Harrington & Cassidy, 1999; Stevens, 2000; Hunt, 2009). Many phonological and phonetic descriptions distinguish [j, w] from [i, u] on the basis of phonotactic criteria, noting that the segments are considered glides when they function as syllable onsets, and vowels when they are syllable nuclei (Selkirk, 1984; Laver, 1994). However, there is evidence that these segments also differ in production, with lower first formant frequencies indicating greater constriction for glides than the corresponding vowels, for example in Amharic, Yoruba and Zuni (Maddieson & Emmorey, 1985), and in American English (Hunt, 2009). Reductions in root mean square amplitude, associated with decreased loudness or intensity, have also been observed, and are similarly indicative of greater constriction for glides relative to vowels (Sun, 1996; Hunt, 2009). A weakening of formant amplitude is often noted for F2-F4 in for glides, particularly F3 for labial-velar glides, and F2 for palatal glides (Harrington & Cassidy, 1999; Espy-Wilson, 1992; Croot & Taylor, 1995). Spectral properties of glides have, however, received little attention crosslinguistically.

Many descriptions also draw on the temporal properties of glides to distinguish them from corresponding vowels, noting that glides generally have short durations, and function as very brief transitional onsets to vowels (Laver, 1994, p. 297). Catford (1977, 1988) considers glides and vowels to have identical articulatory strictures, and explicitly states duration as the basis for separating the two; he describes the glides [w] and [j] as momentary, ultra-short strictures, in contrast to the noticeable duration and prolongability of corresponding vowels [u] and [i]. However, glide durations are likely to vary for different languages; for example, constriction durations for palatal and labial-velar glides in Korean are much lower than for American English glides (S.-K. Kang, 2012).[2] In addition, as made clear by Maddieson (2008), short durations cannot be an inherent characteristics of glides; though typologically uncommon, there is evidence for contrasts between singleton and geminate glides in a number of languages.

5.2.2 Glides and geminate typology

Crosslinguistic surveys of consonant gemination have found that there is enormous diversity in the number and nature of quantity contrasts in the world's languages (Blevins, 2004, 2008), but certain patterns have also emerged, including that less sonorous segments such as stops, and particularly voiceless stops, are among the most preferred consonants for contrasts based on duration differences. Glides such as [w] and [j] are among the least likely segments to be found geminated, and a relationship between sonorancy and the markedness of geminacy has been proposed. Podesva (2002, cited in Dmitrieva, 2012) and Kawahara (2007) have argued that because the formant and intensity characteristics of glides and other sonorants are typically more vowel-like, with less distinct boundaries in relation to neighbouring vowels, they thereby pose a greater challenge to the perceptibility of constriction duration. Results comparing the amplitude of different types of consonants relative to neighbouring vowels, for example in Egyptian Arabic and Persian, show that sonorants, and particularly the palatal glides in those languages, are more similar to vowels in terms of amplitude (Kawahara, 2007; Hansen, 2012; Hansen & Myers, 2017). In the same studies, perception results for singletons and geminates are also presented, and indicate that identification of length contrasts for sonorants was indeed more difficult than for obstruents. However, results showing the opposite are found elsewhere, for example by Dmitrieva (2012) (though no glides were among the sonorants in her study).

It is worth emphasising that the proposed markedness of geminate sonorants, and

[2] It is worth noting, however, that constriction duration is not often among measures reported for glides, likely in part due to the challenges of segmentation. Where glide durations are reported, segmentation criteria vary. These matters are discussed in detail in 5.4.

glides in particular, is based on perceptual rather than production factors. There are some suggestions that attempts to lengthen a glide will result in either a vowel or a fricative, with lengthening necessitating either a change in category, or a change in the production (Dieth, 1950, cited in Maddieson, 2008). However, Kawahara (2007) notes that there should be no articulatory or aerodynamic impedance to sustaining sonorant articulations, as their voicing can be sustained without a buildup in intraoral air pressure. This likely depends on the precise nature of the glide articulation; there is evidence, in comparisons of glides and their corresponding vowels, that a narrower constriction does increase oral pressure, and perception results indicate that amplitude differences associated with the narrower constriction are a salient cue in distinguishing at least singleton glides from corresponding vowels (Hunt, 2009). The lack of quantitative production data for geminate sonorants, and glides in particular, limits the usefulness of generalisations regarding their nature and perceptibility, and Dmitrieva (2012, pp. 240–246) suggests that the relationship between sonority and the markedness of gemination is likely more complicated, and far from resolved based on available information. Despite their rarity and, in some cases, presumed impossibility, geminate glides are found in languages around the world, from linguistic groups including Indo-European, Finno-Ugric, Dravidian, Austronesian, Oto-Manguean, Afro-Asiatic, Niger-Congo, and Nilo-Saharan (see overview in Maddieson, 2008).

5.2.3 Geminate glides in languages of Africa

For languages of the African continent, available overviews indicate that geminate glides appear more often in Afro-Asiatic languages than those of the Niger-Congo or Nilo-Saharan phyla, but the typological picture is likely limited by the availability and accessibility of descriptive data. While geminate glides have only been noted for two Nilotic languages in overviews by Maddieson (2008) and Blevins (2008) (Anywa and Lango, in the Western Nilotic branch), evidence from other sources indicates that a contrast between between two series of glides is present in a number of the 21 or more Eastern Nilotic languages. As noted in 2.2.4, it has not been observed for languages in the Bari branch of Eastern Nilotic, but in the Lotuxo-Teso branch it is found in most of the Lotuxo-

Maa languages, and possibly some of the Teso-Turkana languages (refer to Figure 1.3 for a Nilotic family tree). Though the relationship between glides in Eastern Nilotic languages has received very little discussion, there are some signs that the contrast may have a common origin across these languages. Lexical comparisons show some correspondences between geminate labial-velar glides in certain languages and sequences of bilabial or velar stops followed by labial-velar glides in others, and sequences of velar stops and close back vowels have been suggested as the ultimate source of these (Vossen, 1982, pp. 249–252; Dimmendaal, 1983b, p. 14). The origins of the geminate palatal glide are particularly mysterious, and it appears to have been an innovation among the Lotuxo-Maa languages (Vossen, 1982, pp. 273–74). It is one of several reflexes of a hypothesised alveopalatal stop in Proto Eastern Nilotic (Vossen, 1982, p. 235). However, these speculations are limited by the lexical data available for crosslinguistic comparison, as well as the level of detail in available phonological descriptions. The terminology used to describe the contrast also differs; it is variously described as singleton/geminate, weak/strong or lenis/fortis by different authors, and for different Eastern Nilotic languages. These varied labels could well be indicative of actual differences in the implementation of the contrast, a matter addressed further below. As discussed in 2.2.4, similar contrasts among glides (and other consonants) are also attested in all the southwestern Surmic languages (de Jong, 2004), which, though from a different branch of the Eastern Sudanic group of Nilo-Saharan, are spoken in close proximity to several Eastern Nilotic languages. The Surmic language Tennet is in fact spoken in the midst of Lopit (see 1.3.3), and reportedly has a contrast of this sort among glides (Randal, 1998). Consonantal length contrasts are suggested to be an areal feature shared by some Surmic and Nilotic languages (de Jong, 2004, p. 146).

5.2.4 Proposed glide contrasts in Lopit

Among the few authors who have made phonological observations on Lopit, all have proposed that in the consonantal inventory, some consonants of the same place, manner and voicing have a distinction involving, to some extent, length differences (Vossen, 1982; Turner, 2001; Stirtz, 2014b). Some possible additional cues have also been suggested.

Data collected in the current study shows similar evidence for such a contrast, which, based on impressions of length, I have so far referred to as being a contrast between singleton and geminate consonants. Among the phonemic segments proposed in 3.3 are /tː, dː, nː, lː, wː, jː/, as geminate consonants, contrasting with singleton counterparts /t, d, n, l, w, j/. The contrast between the alveolar trill /r/ and tap /ɾ/ could also be considered part of the same pattern. Though there are some differences in the findings and analyses of other authors discussing this type of contrast in Lopit, as discussed throughout Chapter 3, there are two main things their observations have in common; firstly, that among stops, nasals and liquids, the contrast is mainly found at the alveolar place of articulation, and secondly, that the contrast is present for both labial-velar and palatal glides. The prevalence of alveolar geminates is not unusual, given that this is a crosslinguistically preferred place of articulation for quantity contrasts (Thurgood, 1993). However, it should be recalled that as noted in 3.3, most of the alveolar quantity contrasts in Lopit appear to have a low functional load, based on how often they occur in entries in the lexical database, with the exception of the contrast between /t/ and /tː/.[3] Of particular interest in the present study is the proposed contrast between singleton and geminate glides, which can be observed both intervocalically and word-initially (as seen earlier in Table 3.5). Vossen (1982, pp. 189–192) similarly proposes "two glides occurring both short and long", and Turner (2001, pp. 7–12), who groups consonants into 'strong' and 'weak', suggests /wː, jː/ as 'strong' consonants, distinguished from 'weak' /w, j/ by length and friction. As in the present study, he finds evidence for the contrast word-initially. Stirtz (2014b, pp. 10–11) also discusses the possible contrast among glides in terms of consonant length, but, in the absence of much data indicating a word-initial contrast, prefers an analysis involving sequences of two identical consonants across a syllable boundary.[4] Taken together, these observations suggest that Lopit speakers may make use of length, and potentially other characteristics, to distinguish glides at the same place of articulation. The correlates of

[3] However, given that /nː/ is used in a number of demonstratives, it is quite common in naturally-occurring speech. While this project has not included analyses of phoneme frequencies, these will be of interest in further work.

[4] As noted in Chapter 3, this analysis is most likely preferred for practical reasons, influenced by the orthographic goals of the study. Word-initial /wː/ is transcribed for one word (in both singular and plural forms) in Dorik and Ngutira data provided in Stirtz (2014b, p. 48).

quantity contrasts among glides are, however, not well understood.

5.2.5 Temporal correlates of gemination

Constriction duration is held to be the primary phonetic correlate of singleton/geminate contrasts (e.g. Lahiri & Hankamer, 1988). Given that stops are the most common type of consonant to exhibit length contrasts, it is usually the period of complete occlusion between articulators in the oral cavity which is of interest. Surveys of phonetic findings show a relationship between the proposed phonological length of consonants and their phonetic duration in a large number of languages, and where other cues are present, duration appears to be the most consistent correlate of singleton vs. geminate consonants across speakers and segment types (Ham, 2001; Ridouane, 2010; Hamzah, 2013; Kawahara, 2015). For stops, geminates generally have closure durations approximately 1.5–3 times greater than those of singletons (Ladefoged & Maddieson, 1996b, p. 92). However, the extent to which singleton and geminate consonants differ in terms of duration varies for different languages; Turkish geminate consonants are at the higher end of this range, being three times longer than their singleton counterparts (Hankamer, Lahiri & Koreman, 1989), while Norwegian geminate consonants may be as little as 1.38 times longer than singletons (Fintoft, 1961). In addition to varying for different languages, duration ratios for singletons to geminates may vary within a language, due to factors such as word position. In Tashlhiyt Berber, which permits geminates in all positions, the duration difference between singletons and geminates is smallest intervocalically, and larger word-initially and word-finally (Ridouane, 2007). Maddieson (2008) notes that length contrasts in Itunyoso Trique are realised with lower duration values word-medially than word-initially, and that this pattern also applies to length contrasts among glides.

Duration results for geminate compared to singleton glides have been reported in a small number of studies, and are briefly summarised here (while recalling that among segment types, glides are often quite short in general).[5] In the Austronesian language

[5]Summaries are made with reference to duration ratios, rather than values in milliseconds, given the differences in data types and approaches to elicitation and segmentation. In the studies mentioned here, reported durations of singleton glides range from 36–106ms, and reported durations of geminate glides

Buginese, only the palatal glide can occur geminated, and data for two speakers show that geminate /jː/ is 1.8 times longer than singleton /j/ (Cohn, Ham & Podesva, 1999). In Madurese, another Austronesian language, both the palatal and labial-velar glides can be geminated. Pooled results for these, for two speakers, show the geminates to be 1.5 times longer than the singletons (Cohn et al., 1999). For Lebanese Arabic, results for the pharyngeal approximants and labial-velar approximants are treated together, and geminate approximants are shown to be 1.96 times longer than singletons (Khattab & Al-Tamimi, 2014).[6] Reported data for Persian geminate /jː/ shows that it is on average 1.75 times longer than singleton /j/ (Hansen & Myers, 2017). It has been suggested that in languages with length contrasts across all manners of articulation, those for glides may be realised less clearly (as indicated by smaller duration ratios, and more overlap in duration values for singletons compared to geminates), for example by Aoyama (2005) and Aoyama and Reid (2006), based on data from Guinaang Bontok, an Austronesian language of the Philippines. In Guinaang Bontok, geminate /wː/ is 1.69 times longer than singleton /w/, and geminate /jː/ is 1.39 times longer than singleton /j/, and these ratios are at the lower end compared to those for laterals, nasals and plosives. However, other comparisons have found little difference in duration ratios for glides compared to other manners of articulation, such as for Egyptian Arabic (Kawahara, 2007), or suggest that ratios for glides relative to other manners of articulation vary depending on the language (Cohn et al., 1999; Khattab & Al-Tamimi, 2014; Hansen & Myers, 2017). Little other duration data for geminate glides is available, likely both due to their rarity and also to the difficulty in reliably segmenting and measuring approximants, as discussed further in 5.4. The limited production data means that generalisations pertaining to the reliability of length contrasts among glides are likely to be premature.

Duration may also covary with phonological consonant length beyond the relevant consonant; many studies have found that vowels preceding geminate consonants are shorter than those preceding singletons, though this tendency is not found in all languages (see overviews in Ridouane, 2010; Hamzah, 2013; Kawahara, 2015). Pre-geminate

range from 63–180ms.

[6] Palatal approximants can also be geminated in Lebanese Arabic, but were not included in the study.

vowels are shortened in Italian, for example (Esposito & Di Benedetto, 1999), but there may also be little difference between vowels preceding singletons and geminates, as in Egyptian Arabic (Kawahara, 2007). Vowels preceding geminates may even be longer, as in Japanese (Idemaru & Guion-Anderson, 2009). In Swedish, there is a complementary relationship between vowel and consonant length; long vowels precede singleton consonants, and short vowels precede geminates, and also show differences in vowel quality (Engstrand & Krull, 1994). Specific data on the duration of vowels preceding singleton and geminate glides is extremely limited; Cohn et al. (1999) note that, in general, vowels preceding geminates are substantially shorter than those preceding singletons, which presumably applies across manners of articulation in their Buginese and Madurese phonetic data, while in Egyptian Arabic, there is no duration difference between vowels preceding singleton and geminate glides, as for vowels preceding other consonant manners (Kawahara, 2007). For Persian, Hansen and Myers (2017) found a tendency for vowels preceding geminates to be slightly longer than those preceding singletons, though vowels preceding geminate palatal glide /jː/ were only 1.01 times longer than those preceding singleton /j/, and the difference was not significant.

5.2.6 Other phonetic correlates of gemination

For stops, other phonetic correlates have also been found, such as in burst duration and amplitude, and in voice onset time (Hamzah, 2013; Lahiri & Hankamer, 1988; Arvaniti & Tserdanelis, 2000; Ridouane, 2010). Of particular interest for the present study are some non-temporal characteristics which have been observed among sonorants, for example amplitude differences, which relate to percepts of loudness or intensity. As noted earlier, Kawahara (2007) found that in Egyptian Arabic, consonants of different manners of articulation have different amplitudes relative to neighbouring vowels, with large differences for obstruents, medium-sized differences for nasals, and small differences for approximants. When comparing the relative amplitude for singleton and geminate consonants at the same place of articulation, he found that for geminate consonants, the drop in amplitude tends to be larger than for singletons. However, the plotted results suggest that any difference in relative amplitude between singleton /j/ and geminate /jː/ is very small (perhaps less than 1dB; statistical results are not provided). It is worth noting that this amplitude comparison was focused on transitions, and took, as measurement points, the last periodic wave of the preceding vowel, and compared it to a point at the left edge of the following consonant (15ms into the closure). In a comparable experiment, Hansen (2012) and Hansen and Myers (2017) investigated the intensity difference relative to preceding vowels for Persian singleton and geminate consonants, and similarly found a larger drop in intensity for geminate consonants than for singletons. Though the size of the drop in general is smaller among sonorants, the 2dB difference in relative amplitude is significant for /jː/ compared to /j/. In their experiment, measurements were taken from the midpoint of the relevant consonant and the midpoint of the preceding vowel.

Though formant data are not reported in these studies, it is possible that these differences relate to greater constriction for the geminate compared to singleton glides. As noted earlier, there is evidence that glides differ from vowels with similar strictures by lower first formant frequencies, but also by lower RMS amplitude (Sun, 1996; Hunt, 2009). While there is a relationship between formant frequencies and overall amplitude, Hunt (2009) argues that the differences in RMS amplitude, particularly when glides are adjacent to close vowels, are too large to be explained by adjustments to shape of the vocal tract filter alone; she proposes that glide constrictions may be narrow enough for there to be a build-up of oral pressure behind the constriction, resulting in a weakening of the signal, with various acoustic consequences including overall amplitude reduction. Furthermore, in the related perceptual study, listeners appear to give more weight to amplitude cues than to F1 cues in distinguishing glides from vowels. Given the articulatory similarities between close vowels and both singleton and geminate glides, it would not be surprising if these sorts of cues were also exploited in distinguishing articulatorily similar glides. Maddieson (2008) notes, in comparing intervocalic tokens of singleton compared to palatal glides in Itunyoso Trique, that the geminate has “slightly more extreme” F1 and F2 values, and amplitude values 2dB lower than for the singleton. These characteristics, indicative of decreased sonority for geminate glides, would likely also help to maintain the consonantality of a long glide.

Other studies have found spectral differences between singleton and geminate sonorant consonants; for example, in Italian, the geminate lateral /lː/ tends to have a lower frequency for the first formant, and higher frequencies for the second and third formants, indicative of a more palatalised articulation than that of the singleton lateral /l/ (E. Payne, 2005). Similarly, in Malayalam, geminate alveolar /lː/ and retroflex /ɭː/ have lower first formant frequencies and higher second formant frequencies than their singleton counterparts /l/ and /ɭ/ (Local & Simpson, 1999). For Italian /lː/ and /l/, observations of spectral differences are supported by electropalatographic results showing an articulation which is both more palatalised and more laminal for /lː/ compared to /l/, with similar results for other coronal pairs (E. Payne, 2006). While very few studies have investigated differences beyond duration for vowels adjacent to geminates, there is some evidence that intervocalic geminate consonants may also have spectral effects on surrounding vowels, in addition to durational effects. If there are articulatory differences in the consonants, it is not unexpected that this would also be reflected in adjacent segments. For example, in Malayalam, vowels preceding geminate /lː/ are more peripheral than those preceding singleton /l/, as evidenced by lower first formant values and higher second formant values, though for vowels preceding geminate /ɭː/, higher first formant frequencies suggest a more open rather than more close quality compared to those preceding singleton /ɭː/. Impressions of phonetic differences beyond duration, on segments beyond the geminated consonant, lead Local and Simpson (1988) to argue that in Malayalam, gemination is a long-domain phenomenon, and that this possibility should be considered in the treatment of gemination more generally. However, other studies investigating the formant characteristics of vowels adjacent to geminate and singleton sonorants have found little difference (Khattab & Al-Tamimi, 2015; Arvaniti & Tserdanelis, 2000).

5.2.7 Gemination and fortition

Based on the findings showing articulatory as well as durational differences, E. Payne (2006) suggests that gemination in Italian should more generally be considered a fortitional process, if fortition is taken to be associated with greater articulatory contact. This is one of many ways the terms 'fortis' and 'lenis', related to the concept of consonantal strength or effort, have been used in the phonetic and phonological literature, with some overlap with applications of the terms 'tense' and 'lax' to consonantal contrasts. The labels 'fortis' and 'tense' have been variously applied to articulations held to involve, compared to 'lenis' or 'lax', greater respiratory energy, articulatory energy, laryngeal and supralaryngeal tension, a lack of vocal fold vibration, more precise/less variable articulatory targets, more constricted or peripheral articulations, longer closures, and various combinations of these (see discussions in e.g. Malécot, 1970; Catford, 1977; Kohler, 1984; Ladefoged & Maddieson, 1996b; Butcher, 2004; DiCanio, 2012b; Stoakes, 2013). The phonetic consequences of such articulations may be apparent in measures of intraoral air pressure and flow, voice onset time, release burst amplitude, duration, formant frequencies, and fundamental frequency, among others. There is language-specific evidence, based on detailed phonetic work, of consonantal distinctions drawing on a contrast of this sort; the three-way voiceless stop contrast found in Korean is a well-known and relatively well-described example, in which both intraoral air pressure and airflow, in addition to voice onset time and other phonetic correlates, distinguish fortis, lenis and aspirated stops (Cho, Jun & Ladefoged, 2002). However, a single crosslinguistically reliable phonetic correlate of either 'fortis' or 'tense' has not emerged from experimental work. As noted by Ladefoged and Maddieson (1996b), where different phonetic correlates of putative fortis/lenis contrasts covary, it may not always be clear to what extent they are independent, and which should be considered primary. It is worth noting that, as for the discussion of geminates, most discussion of fortis/lenis and tense/lax consonants has focused on obstruent contrasts, particularly those which are also often conceived of as voicing contrasts. It is less clear how, or whether, proposals for consonantal fortition or tenseness apply to sonorants, and approximants in particular.

There is clearly some overlap with phonetic correlates observed (or proposed) for fortis/tense consonants and those noted for geminate consonants, most notably differences in closure duration relative to lenis/lax/singleton, but also in correlates such as voice onset time, burst amplitude and formant frequencies (recalling that the non-temporal correlates of gemination appear to be more variable crosslinguistically, though they have also received less attention). This presents a descriptive challenge, where terminological preferences may be influenced by a number of factors. As noted by Jaeger (1983) and

Ladefoged and Maddieson (1996b), fortis/lenis and similar labels are sometimes used as cover terms for language-specific phonological distinctions; they may be particularly appealing when it is difficult to identify auditorily which cues are primary, or when an observed phonological pattern is implemented in slightly different ways across the consonant inventory. The varying use of these terms has led to their disparagement by some authors, for example Catford (1977, pp. 199–204), who argues that "the terms tense/lax, strong/weak, fortis/lenis, and so on, should never be loosely and carelessly used without precise phonetic specification."[7] This may not always be possible early on in investigations, but as phonetic data become available for more languages, there is evidence that for many contrasts described as fortis/lenis, duration is a significant and consistent cue. This is the case, for example, in several Australian Indigenous languages (Jaeger, 1983; Butcher, 2004; Stoakes, 2013; Stoakes, Butcher & Fletcher, 2014), though with evidence that intraoral pressure is also a significant, and independently controlled, cue (Butcher, 2004; Stoakes, 2013; Stoakes et al., 2014).[8] Elsewhere, phonetic data have illustrated that some contrasts traditionally described as fortis/lenis may be more appropriately described as length contrasts. For example, in a number of Oto-Manguean languages, duration has emerged as a primary correlate of consonants typically described as 'fortis' in the literature, supplemented by differences in glottal width (Jaeger, 1983; Avelino, 2001 (cited in DiCanio, 2008); Leander, 2008; DiCanio, 2008; DiCanio, 2012b). Other correlates earlier held to be indicative of a difference in strength are shown instead to be predictable consequences of the duration differences (DiCanio, 2008, 2012b).

In response to suggestions that obstruent contrasts in Tashlhiyt Berber may be better considered a matter of tenseness or fortition rather than gemination (some drawing on theoretically-based arguments that contrasts between geminates and singletons are not possible word-initially), Ridouane (2007, 2010) explores the phonetic manifestation of the contrast in detail, and finds duration to be the primary correlate. Though some ad-

[7]Some parallels can be drawn between the somewhat controversial nature of the labels fortis/lenis and their relationship or otherwise to particular acoustic or articulatory correlates, and the use of labels such as +ATR and -ATR, as discussed in 2.3.1.

[8]Furthermore, in Bininj Gun-Wok this differs from patterns observed for geminates (homorganic stop clusters) in the same language; these have long durations but do not draw on pressure changes in the same way.

ditional cues are observed, such as in burst amplitude, he finds that duration is the most reliable and consistent correlate of consonant category, and argues that other correlates which are contextually limited, or more variable, act as secondary cues which serve to enhance the contrast by increasing the perceptual distance between singletons and geminates. As pointed out by Kawahara (2015), while constriction duration is the most cross-linguistically reliable correlate of proposed singleton/geminate contrasts, such contrasts also show the "multiplicity of acoustic cues" typical of phonological contrasts more generally (Kawahara, 2015, with reference to Kingston & Diehl, 1994). These findings show that the boundaries between gemination and fortition/tenseness are less than clear-cut, and the criteria and motivations for preferring one over another are influenced by many factors. It is clear from available descriptions of Nilo-Saharan languages that 'fortis' has been used in various ways; for example, in descriptions of the Surmic language Didinga, a lenis/fortis opposition is described for every consonant type, including glides, but de Jong (2004, p. 145) specifically notes that the terms "are used in the popular sense, not in the way phonetics uses them", and that the fortis consonants are in fact interpreted as doubled compared to the lenis consonants, though some additional impressionistic differences are noted for specific consonant pairs. Similarly, while some descriptions of Eastern Nilotic languages such as Otuho and Lopit have primarily referred to length in describing contrasts between consonants of the same place, manner and voicing, other descriptions have used terminology such as 'strong' and 'weak' in order to encompass other possible phonetic differences, in addition to (or instead of) length, observed for proposed stop, nasal, and approximant contrasts (as discussed further below).

5.2.8 Impressions of Eastern Nilotic glide characteristics

The different terminology that has been used to describe Eastern Nilotic glide contrasts is worth considering, as it suggests that, as has been observed for length contrasts among other consonant types in other languages, or some contrasts traditionally described as fortis/lenis, cues beyond duration differences may be present. As discussed in 3.3.4 and 5.2.4, existing descriptions of glides in Lopit all characterise them as short vs. long at two places of articulation (Vossen, 1982; Turner, 2001; Stirtz, 2014b), though Turner also suggests frication as present for geminate glides compared to singletons, and groups them with other consonants as 'strong' compared to 'weak'. In the overview in 2.2.4, it was noted that Vossen (1982) uses the same terminology of long vs. short for the four proposed glides in Dongotono, Lokoya, and Otuho, all in the same immediate Lotuxo family. However, other authors on Otuho describe /wː/ and /jː/ as 'fortis' (Duerksen, 2004), or 'strong', compared to 'weak', as Coates (1985) does, despite using the length diacritic for the phonemic representation. [9] For the Maa group of languages, pairs of glides are similarly noted by various researchers; for Maasai, Tucker and Mpaayei (1955) describe these as 'weak' compared to 'strong', and the same terminology is used by Rasmussen (2002) for Il-Keekonyokie Maa and by Levergood (1987) for Arusa Maa. They are described as lenis compared to fortis by D. L. Payne (2012). Levergood (1987, p. 18) adds that the 'weak' glides "are not as approximated as in English", and the 'strong' glides "are longer and more approximated than in English". Similar observations are made by Tucker and Bryan (1966, p. 448), who note that the long and/or strong glides are a noticeable feature of Maasai, and that "besides being pronounced longer and with more emphasis, *yy* and *ww* belong to the 'close' category of sounds, while *y* and *w* are 'open'." Contrasts between /w, wː, j, jː/ have also been noted for related varieties Samburu (Vossen, 1982), Camus (Vossen, 1982; Heine, 1980) and Ngasa (Ongamo) (Vossen, 1982). The presence of the contrast is likely to be marginal at best among Teso-Turkana languages, but a 'long' labial-velar glide, analysed as a sequence of /uw/, has been noted in some Turkana words (Dimmendaal, 1983b), and Vossen (1982, p. 182) notes geminate /jː/ in a few Teso words.

Little has been said about the nature of glide contrasts in the Surmic languages, which, as noted in 5.2.3, constitute a different branch of Eastern Sudanic but are spoken in close proximity to many Nilotic languages. For Didinga, de Jong (2004, p. 145) uses the terms 'lenis' and 'fortis' (but as noted above "in the popular sense", intended to be interpreted as primarily referring to length differences), but also uses the terms 'light' and 'heavy' as

[9] As noted in the crosslinguistic overview in Chapter 2, the varying representations of long/strong glides in the Nilotic literature are reported here using IPA conventions, as /wː, jː/, but some authors transcribe these as /ww, yy/ and /wu, yu/. While Coates (1985) does represent these glides as /wː, jː/, Gilley (1992, pp. 38–39) notes that in personal communication, Coates specifies that "strong consonants are fortis productions and the colon does not indicate length".

'translations' of these, and notes some other associated cues. These include observations of some frication for geminate compared to singleton glides (de Jong, 2004, p. 145), as also suggested by Turner (2001, pp. 7–12) for Lopit. It seems, then, that terminological preferences are not always reliable indicators of the perceived nature of these contrasts, but at the same time, it is clear that some researchers have been attuned to characteristics other than duration. Length differences are a salient feature of the contrast for many, but remarks on the 'close' or 'more approximated' nature of the geminate glides suggest that in at least some languages, articulatory differences indicative of a potentially more consonantal articulation may be providing additional or alternative cues.

Some comments from those studying Eastern Nilotic languages suggest preferences for particular vowel qualities in the environment of geminate glides, and draw some connections between this and the ATR vowel system. For example, as discussed in 3.4.3.3, Tucker and Mpaayei (1955, p. 240) have observed that [+ATR] vowel qualities are preferred not just preceding other [+ATR] vowels, as part of vowel harmony processes, but also before 'strong' consonants /wː/ or /jː/. Some similar remarks are made by Muratori (1938, pp. 10–11) for Otuho, and in later work, Coates (1985, pp. 100–101) states that /wː/ and /jː/ only occur between [+ATR] vowels in Otuho, and suggests that the ATR system is a conditioning factor, though 'weak' /w/ and /j/ can apparently occur with either [+ATR] or [-ATR] vowels. For Lopit, Turner (2001, p. 50) notes a general tendency for /wː/ and /jː/ to occur with [+ATR] vowels, while impressions in the current study are that only vowels preceding (and not following) geminate glides tend to exhibit a change in vowel quality. Furthermore, indications are that this effect seems to be limited to the syllable immediately preceding a geminate glide, and does not persevere leftwards in the way that ATR harmony does, suggesting that it is likely a process of localised coarticulation (see 3.4.3.3 for discussion). A separate issue is whether glides, regardless of any length contrast, show distinctions on the basis of ATR, as suggested for example for glides in Mundari (Stirtz, 2014a, pp. 9–10). However, to my knowledge, there is no phonetic data on interactions between geminate glides and ATR in Eastern Nilotic languages, nor on the phonetic characteristics of the glides themselves.

5.3 Hypotheses

From the preceding discussion, and relevant sections of Chapter 2 and Chapter 3, a number of observations and considerations arise relating to glides in Lopit, and the phonetic characteristics of glides more generally. These inform the approach to Research Question 4, which is the focus of this chapter: "What are the phonetic characteristics of contrastive glides in Lopit?" Three hypotheses were developed for testing in this experiment, and the motivations for these are discussed below.

A contrast between two types of labial-velar glide and two types of palatal glide was proposed in 3.3, and similar observations have been made by other authors investigating Lopit phonology (Vossen, 1982; Turner, 2001; Stirtz, 2014b). In all of these descriptions, length differences have been impressionistically noted for pairs of glides at the same place of articulation (in addition to some other pairs of consonants). While gemination among glides is uncommon, and has rarely been investigated, there is good evidence that it is possible (Maddieson, 2008), and that duration differences correlate with proposed length differences among glides in other languages (e.g. Cohn et al., 1999; Aoyama & Reid, 2006). Given this, it is hypothesised that:

1. Lopit has four contrastive glides: labial-velar /w, wː/ and palatal /j, jː/. /wː/ and /jː/ can be characterised as geminate glides, and are distinguished from /w/ and /j/ by higher duration values.

Differences in constriction duration are the most crosslinguistically reliable phonetic correlate of proposed consonantal length differences, but preceding vowels may also show duration differences; for many languages, there is a tendency for vowels preceding geminates to be shorter than those preceding singletons, though in some cases they may be the same length, or those preceding geminates may in fact be longer (see overviews in Ridouane, 2010; Hamzah, 2013; Kawahara, 2015). While most reported data pertains to vowels preceding stops, there are some suggestions that pre-geminate shortening may apply to vowels preceding geminate glides in at least some languages (Cohn et al., 1999), though results differ for other languages (Kawahara, 2007). Given this, it is hypothesised that:

2. In Lopit, vowels preceding putative geminate glides /wː, jː/ have lower duration values than those preceding putative singleton glides /w, j/.

Observations on glide pairs in Lopit and in other Eastern Nilotic languages also include impressions of a closer or more constricted articulation for geminate compared to singleton glides (or strong/fortis compared to weak/lenis glides) at the same place of articulation, in addition to some impressions of differing qualities for preceding vowels (Turner, 2001; Tucker & Bryan, 1966; Levergood, 1987). Work comparing glides to close vowels with similar strictures demonstrates that glides have lower F1 frequencies, indicative of greater constriction which is also associated with reductions in root mean square amplitude (Maddieson & Emmorey, 1985; Sun, 1996; Hunt, 2009). There are some indications that geminate glides may exploit these characteristics in a similar way, with lower F1 and amplitude values compared to singletons (Maddieson, 2008; Hansen, 2012; Hansen & Myers, 2017). Given this, it is hypothesised that:

3. In addition to duration, phonetic cues including lower first formant frequencies and lower RMS amplitude differentiate Lopit /wː/ and /jː/ from their counterparts /w/ and j/ respectively, and furthermore, evidence for lower first formant frequencies will be apparent in vowels preceding geminate glides.

5.4 Methodology

5.4.1 Participants

The participants in this production study were three male speakers of Lopit (AL, DA and VH), and two female speakers (EA and JT). All five participants are from two villages in the Dorik dialect area in the Lopit mountains, and are members of the Lopit community in Melbourne, introduced in 1.6.1. The three male speakers also participated in the vowel study in Chapter 4 and the tone study in Chapter 6.

5.4.2 Materials

The stimuli for this experiment were selected from the lexical database constructed in the course of the wider project, as outlined in 1.6.2. This lexical database focuses on data for the Dorik dialect of Lopit, but consultation of data provided by other researchers shows many segmental correspondences across dialects, including for geminate glides. The selected stimuli include both nouns and verbs. The proposed contrast between singleton and geminate glides is found across word classes, but it does not have the same functional load as other contrasts, and nominal data alone would provide an insufficient number of tokens for experimental study with the lexical data available. It is worth noting that the occurrence of proposed segments /wː, jː/ and /w, j/ in verb stems, and specifically as the first consonant of a verb stem, is good evidence for their contrastive status; this is a position in which all consonantal contrasts apart from the glottal stop are well-represented (as discussed in 3.6).

The materials compiled for this experiment were therefore a set of both nouns and verbs, mostly of 2–3 syllables and exhibiting a range of tonal patterns, with intervocalic examples of /wː, jː, w, and j/. Though Lopit also permits /wː/ and /jː/ to occur word-initially (as well as /w/ and /j/), examples are much less common, so this first experiment on glides in Lopit focuses on medial glides only. 91 words were used in the analysis, and these are listed in Table C.4 in Appendix C. Some examples are shown in Table 5.1. These words include glides flanked by non-close vowels, with a preference for the open vowel /a/ where possible. This preference is partly due to the expected difficulty in segmenting glides adjacent to vowels with very similar acoustic characteristics, and also because there are indications in other work that the way glides are differentiated from adjacent vowels may differ in close vowel compared to non-close vowel environments (Hunt, 2009).[10] Additionally, the preference for open vowels is motivated by sugges-

[10]Namely, that the extent of F1 lowering may be much smaller for glides adjacent to close vowels, due to the limiting factor of the vocal tract walls, and that the glide-vowel distinction in such contexts likely hinges on amplitude reduction and supporting correlates. While formant differences between glides and neighbouring vowels are not the focus of this chapter, it is not clear whether a greater reliance on amplitude differences for glides in close vowel contexts may also have implications for the realisation of singleton-geminate glides in such contexts; it is possible that different cues to glide category may be privileged in different vowel environments.

tions that vowel quality may vary preceding singleton and geminate glides. There is an ATR distinction among the mid (and close) vowels, and as described in 3.4.3.3, [-ATR] vowels /ɛ, ɔ/ are phonemically possible before geminate glides, but may be realised with a closer quality more similar to [+ATR] /e, o/ in that context, and in monomorphemic words it may not be straightforward to identify the ATR category of vowels preceding geminate glides. However, as shown in Chapter 4, the open vowel /a/ does not have a [+ATR] counterpart, and therefore tokens of /a/ will allow for a more controlled subset, without ATR distinctions, to be used in investigating the characteristics of vowels preceding singleton and geminate glides.

Table 5.1: *Examples of wordlist items with intervocalic singleton and geminate glides. (The full list can be found in Appendix C.)*

Geminate		Singleton	
	[wː]		[w]
áwːár	be alive 1SG	áwák	want 1SG
tɔ́wːánàʔ	stay IMP	tɔ́wálàʔ	cough IMP
	[jː]		[j]
íxájːá	pumpkin leaves PL	xíjàjàʔ	porcupine SG
tɛ́jːɛ̀t	pull IMP	tɛ́jɛ̀f	chop IMP

5.4.3 Elicitation and recording procedures

Spoken English prompts were produced to elicit the corresponding target words in Lopit. Given that the proposed contrast between geminates /wː, jː/ and singletons /w, j/ is reflected in the working orthography used in the current project (as *ww, yy* compared to *w, y*), showing the written Lopit target word during elicitation was dispreferred. However, a slideshow with written English prompts was prepared and shown simultaneously. As described in Chapter 4, each token was presented on a separately numbered slide, and participants waited until each slide was manually advanced before producing each successive repetition of a word. This allowed for more consistent productions, in terms of speech rate and pitch, across repetitions. In this experiment, five repetitions of each word were aimed for; extra repetitions were occasionally requested due to e.g. coughing or laughter, and sometimes not all five were produced. Data were recorded in a quiet room at a sampling rate of 44.1kHz and 16-bit depth, using a Zoom H4N audio recorder, MixPre-D pre-amp, and AudioTechnica AT892c headset microphone.

5.4.4 Data processing and analysis

5.4.4.1 Segmentation and labelling

Data were segmented and labelled in Praat (Boersma & Weenink, 2016) with reference to wideband spectrograms and corresponding waveforms. Tiers for word, repetition number, tones and segments were included, and segmental transcription was broad phonetic, using X-SAMPA (Wells, 1995). The vowel-like characteristics of approximants, especially glides, pose a particular challenge to segmentation, and as noted by Harrington and Cassidy (1999, p. 105), the lack of clearly-defined discontinuity in sequences of vowels and approximants may be seen by some as grounds for not segmenting them at all. In their guide to segmentation for durational experiments, Turk et al. (2006, p. 5) rank the segmentability of segment types; approximants are "[t]o be avoided". Nevertheless, there are many reasons why researchers may want to segment glides and other approximants, and there are a range of possible approaches to doing so. These are, however, not always described; Maddieson (2008) points out that in the small number of phonetic studies reporting on singleton and geminate glides, segmentation criteria are rarely mentioned. Where criteria are mentioned, they vary. Aoyama and Reid (2006) opt for a generous approach to singleton/geminate glide duration, as the period between the end of the steady state of a preceding vowel and the beginning of the steady state of a following vowel; elsewhere, the inclusion of long formant transitions as part of the glide is dispreferred in the segmentation of glides more generally, in favour of identifying a consonant steady-state where possible (Keating et al., 1994). This more conservative approach is applied to the segmentation of singleton and geminate palatal glides in Persian, with glide steady states labelled using local F2 maxima and/or F1 minima as onsets, and the same as offsets (Hansen & Myers, 2017). However, although the formant structures of glides are useful indicators of their segmental presence, these are not the only or necessarily the most reliable indicators of transitions; an overall drop in intensity also correlates with glides in general (Harrington, 2010), and is argued to provide the most reliable landmark for identifying boundaries between glides and vowels (Hunt, 2009), supported by weakened upper formants (Espy-Wilson, 1992; Harrington & Cassidy, 1999).

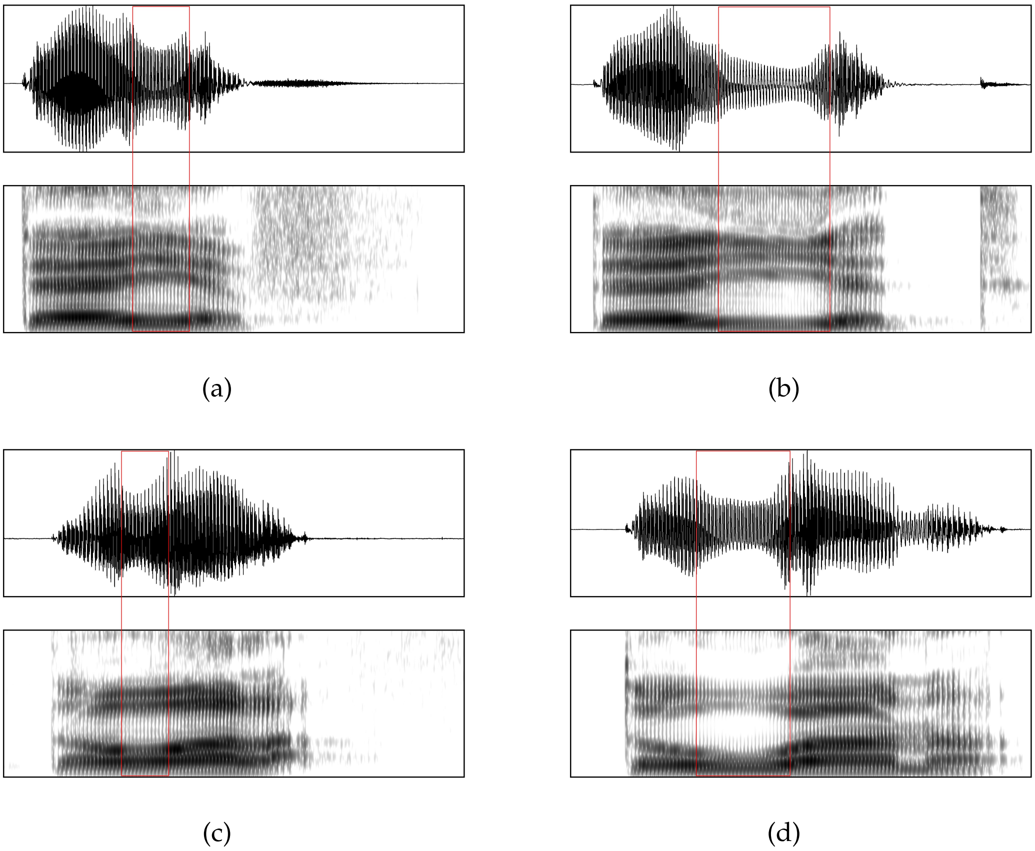


Figure 5.1: *Acoustic waveforms and spectrograms showing example tokens of (a) /tέjὲf/ 'chop* IMP*' and (b) /tέjːὲt/ 'pull* IMP*' (duration 880ms, dynamic range 50dB), and (c) /tɔ́wálàʔ/ 'cough* IMP*' and (d) /tɔ́wːánàʔ/ 'stay* IMP*' (duration 800ms, dynamic range 50dB), indicating portion labelled as glide according to the segmentation criteria used in this study.*

Given these considerations, the labelling procedure followed for these data used the drop in intensity (based on RMS amplitude), and return to a peak, as the primary indicator of glide onset and offset, in addition to visibly weaker upper formants, for syllable-initial segments with vowel-like formant structures (low F1, high/low F2). This is similar to the approach used for segmenting singleton and geminate palatal glides in Lebanese

Arabic (Khattab & Al-Tamimi, 2014). The amplitude criteria tended to correspond with formant changes, sometimes quite abrupt in the case of geminates. Furthermore, as seen in Figure 5.1, the segmented glides include periods of reasonably stable formant structure. While reported glide duration values may differ depending on segmentation criteria, a set of consistently-implemented criteria should allow any meaningful glide patterns suggested by the spectrograms in Figure 5.1 to emerge in quantitative analyses. Given that other impressions of Lopit geminate glides have suggested frication as a possible characteristic of /wː, jː/ Turner (2001, p. 55), it was anticipated that some geminate tokens may need to be excluded from the analysis if frication was indeed present, which would affect formant structures among other things. However, frication was only present for one extremely hyperarticulated token of /wː/, which was also approximately three times as long as other tokens. Some tokens were excluded due to other reasons affecting formant tracking, such as coughing, creakiness, or simply the formants being too weak, as was the case for the third formant in some instances of /wː/. The total number of tokens used in this analysis was 2,384 (/j/ = 604, /jː/ = 648, /w/ = 572, /wː/ = 560).

5.4.4.2 Acoustic measures

After labelling, the data were imported to the Emu Speech Database System (Cassidy & Harrington, 2001) to create a hierarchically linked database and extract acoustic data, and data were then queried and plotted in R (R Development Core Team, 2016) using the `emu/R` package (Harrington et al., 2012). The measures of interest for this experiment are the constriction duration of glides and the duration of vowels preceding glides (ms, extracted in R based on time values for labels in Emu), the frequencies of the first, second and third formants for the glides, and the first and second formants for tokens of /a/ preceding glides (Hz, extracted via the Speech Signal Analysis tool in Emu), and the intensity of glides, and glides relative to preceding vowels, as indicated by root mean square (RMS) amplitude (dB, extracted via the Speech Signal Analysis tool in Emu). Statistical comparisons for F1, F2, and F3 of glides are based on measurements taken at glide midpoints, and time-normalised formant trajectories are shown in addition to plotted midpoint values. Comparisons for F1 and F2 of /a/ tokens preceding glides are based on vowel midpoints. Intensity comparisons are based on RMS amplitude measurements taken at the midpoints of the glides, as well as the difference between these and the RMS amplitude values at midpoints of preceding vowels. Intensity and duration data are shown in boxplots.

5.4.4.3 Statistical tests

The data were tested with Linear Mixed-Effects Models (LMEM) using the `lme4` package in R (Bates et al., 2012), following comparisons between different possible models for each test, and visual checks of homogeneity of variance (homoscedacity) and normal distribution using plots of residuals and fitted values. In this study, the main effect of glide category is investigated. Tests pertaining to glide duration were performed with random effects of speaker and word, including random slopes for speaker. Random effects of speaker and word, with intercepts only, were also used for tests of preceding vowel duration. Comparisons of glide formant values and intensity values also had random effects of speaker and word, with random slopes for speaker except for the comparison of intensity at glide midpoints. For comparisons of preceding vowel formants, random effects included speaker, utterance, and tone category for F1 comparisons, with random slopes for speaker, while F2 comparisons included random effects of word and the sex of the speaker.

The validity of each analysis in this experiment was first checked using a likelihood ratio test, to compare a model including both the fixed and random effects with a model including only the random effects and thereby corresponding to the null hypothesis. The absence of a significant difference between these models indicates that the main effect does not have a more substantial influence on the measure of interest than the random effects, and that the relevant hypothesis must be rejected. A difference between the models suggests that the main effect does have an influence, and the differences between pairs of glides can then be inspected using Tukey's Honest Significant Difference post-hoc tests. Throughout this chapter, results are reported as Pearson's Chi-Square values (χ^2) and associated p-values, with p-values up to 0.05 accepted as significant. The results of the post-hoc tests are summarised in tables throughout, and descriptive statistics

Table 5.2: *Results of Tukey's post-hoc tests for comparisons between glides for duration values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

Glide duration comparison	result
/jː/ ~ /j/	***
/wː/ ~ /w/	***
/jː/ ~ /w/	***
/wː/ ~ /j/	***
/jː/ ~ /wː/	-
/w/ ~ /j/	-

(number of tokens, mean, median, standard deviation, minima, maxima) for glide duration, vowel duration, F1, F2, F3 and intensity are contained in Appendix D (Table D.8 to Table D.17).

5.5 Results

5.5.1 Duration

5.5.1.1 Duration of glides

Figure 5.2 shows the distributions of duration values for medial tokens of glides /wː, w, jː and j/ produced by each participant. There are consistent patterns across the results for all five participants, and clear differences between proposed singleton /w, j/ and geminate /wː, jː/ can be observed. To investigate the main effect of glide category on glide duration, the data were submitted to a mixed-effects model with glide category as a fixed effect and participant and word as random effects. The likelihood ratio test for glide duration data is significant (χ^2(3, N=2384)= 22.07, p<0.001), indicating that glide category does have a substantial effect on duration values. The results of post-hoc tests, summarised in Table 5.2, reveal that duration values for /wː/ are significantly higher than for /w/ by 66 $\pm$ 5 ms, and similarly higher than for /j/ by 68 $\pm$ 6 ms. Duration values for /jː/ are significantly higher than for /j/ by 74 $\pm$ 5 ms, and similarly higher than for /w/ by 72 $\pm$ 5 ms. There are no significant duration differences between geminate /wː/ and geminate /jː/ (p=0.386), nor between singleton /w/ and singleton /j/ (p=0.983).

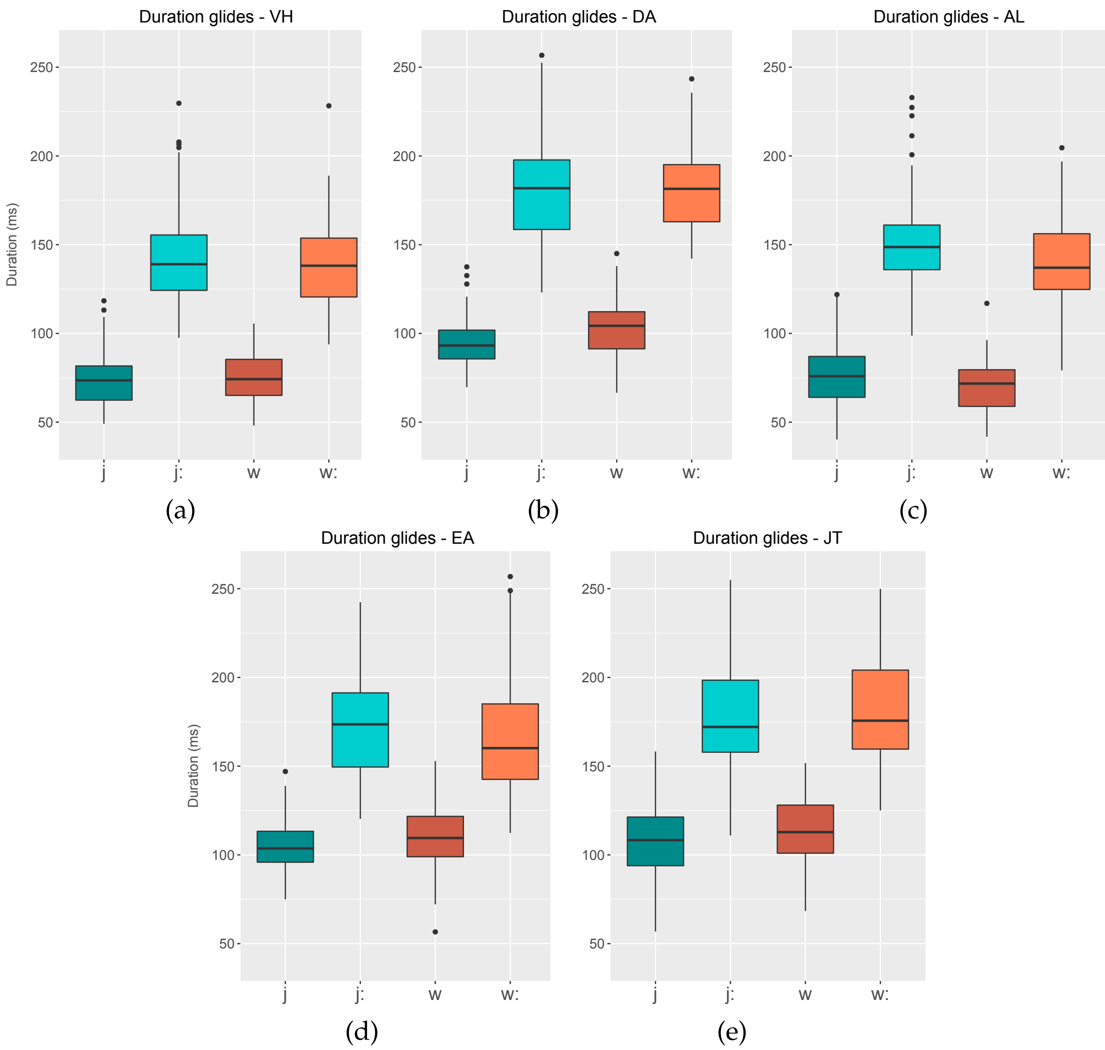


Figure 5.2: *Duration (ms) of singleton and geminate glides, for each participant.*

Table 5.3: *Ratios of singleton to geminate durations.*

Participant	/w/ : /wː/	/j/ : /jː/	/C/ : /Cː/
VH	1 : 1.85	1 : 1.95	1 : 1.90
AL	1 : 1.99	1 : 2.00	1 : 2.00
DA	1 : 1.77	1 : 1.94	1 : 1.85
JT	1 : 1.59	1 : 1.67	1 : 1.63
EA	1 : 1.53	1 : 1.66	1 : 1.59
all	**1 : 1.71**	**1 : 1.82**	**1 : 1.77**

5.5.1.2 Duration of vowels preceding glides

The duration values of vowels preceding /wː, w, jː and j/ are shown in Figure 5.3. Though the differences are less striking compared to the durations of the glides themselves, a tendency towards lower duration values for vowels preceding geminate glides is apparent. The effect of glide category was investigated using a mixed-effects model as above. The significant result of the likelihood ratio test for vowel duration data (χ^2(3, N=2384)= 36.92, $p<0.001$) points towards glide category as having a role in the differences. The results of post-hoc tests are summarised in Table 5.4. These results show that vowels preceding /wː/ are an estimated 28 $\pm$ 7 ms shorter than those preceding /w/, and are similarly 33 $\pm$ 7 ms shorter than vowels preceding /j/. For /jː/, post-hoc tests reveal that preceding vowels are significantly shorter than those preceding /j/ by 34 $\pm$ 7 ms, and similarly 28 $\pm$ 7 ms shorter than vowels preceding /w/. There are no significant differences in duration between vowels preceding the two geminates /wː/ and /jː/ (p=1.00), nor between vowels preceding the two singletons /w/ and /j/ (p=0.81).

As noted, the dataset includes many tokens of /a/ preceding glides, offering an opportunity for some more controlled comparisons to be made between vowels of the same quality. A subset of the data, comprising 1,055 tokens of /a/, was used for an additional comparison of pre-glide vowel duration. Duration values for these are shown in Figure 5.4, and show some similar trends as in Figure 5.3 for all non-close vowels. The

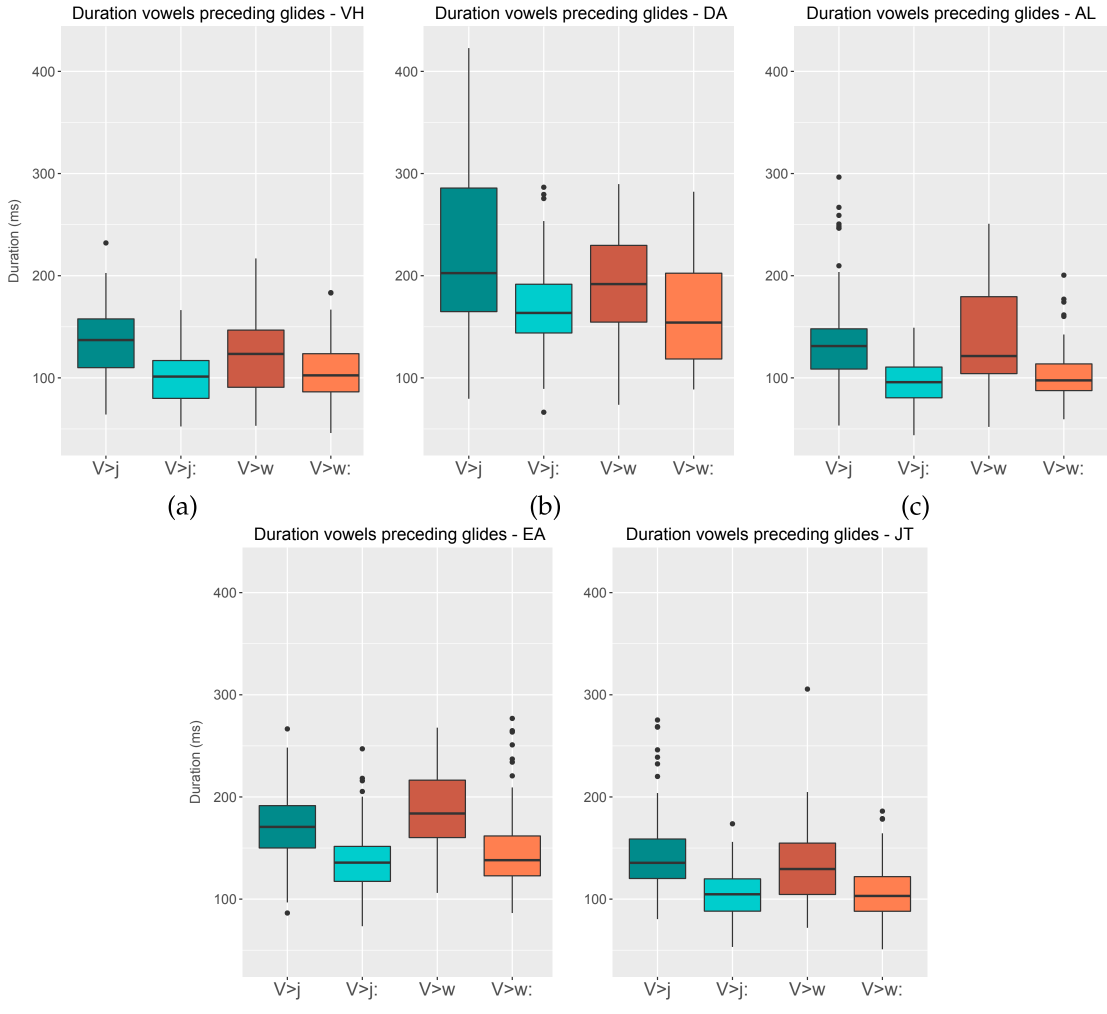


Figure 5.3: *Duration (ms) of vowels preceding singleton and geminate glides, for each participant.*

Table 5.4: *Results of Tukey's post-hoc tests for comparisons between vowels (all tokens, and only /a/ tokens) preceding glides for duration values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

Vowel duration comparison	dur V result	dur /a/ result
before /jː/ ∼ before /j/	***	**
before /wː/ ∼ before /w/	***	**
before /jː/ ∼ before /w/	***	**
before /wː/ ∼ before /j/	***	*
before /jː/ ∼ before /wː/	-	-
before /w/ ∼ before /j/	-	-

likelihood ratio test for /a/ duration values is significant ($\chi^2(3, N=1055)= 21.05$, $p<0.001$), and the results of post-hoc tests are similar to those above. Duration values for /a/ tokens preceding /wː/ are significantly lower than those for /a/ tokens preceding /w/ by an estimated 37 ± 11 ms, and are also lower than for vowels preceding /j/ by 28 ± 9 ms. Similarly, /a/ tokens preceding /jː/ are significantly lower than those preceding /j/ by an estimated 34 ± 9 ms, and shorter than those preceding /w/ by 43 ± 12 ms. There are no significant differences between the durations of /a/ tokens preceding /jː/ and /wː/ ($p=0.93$), or /j/ and /w/ ($p=0.83$).

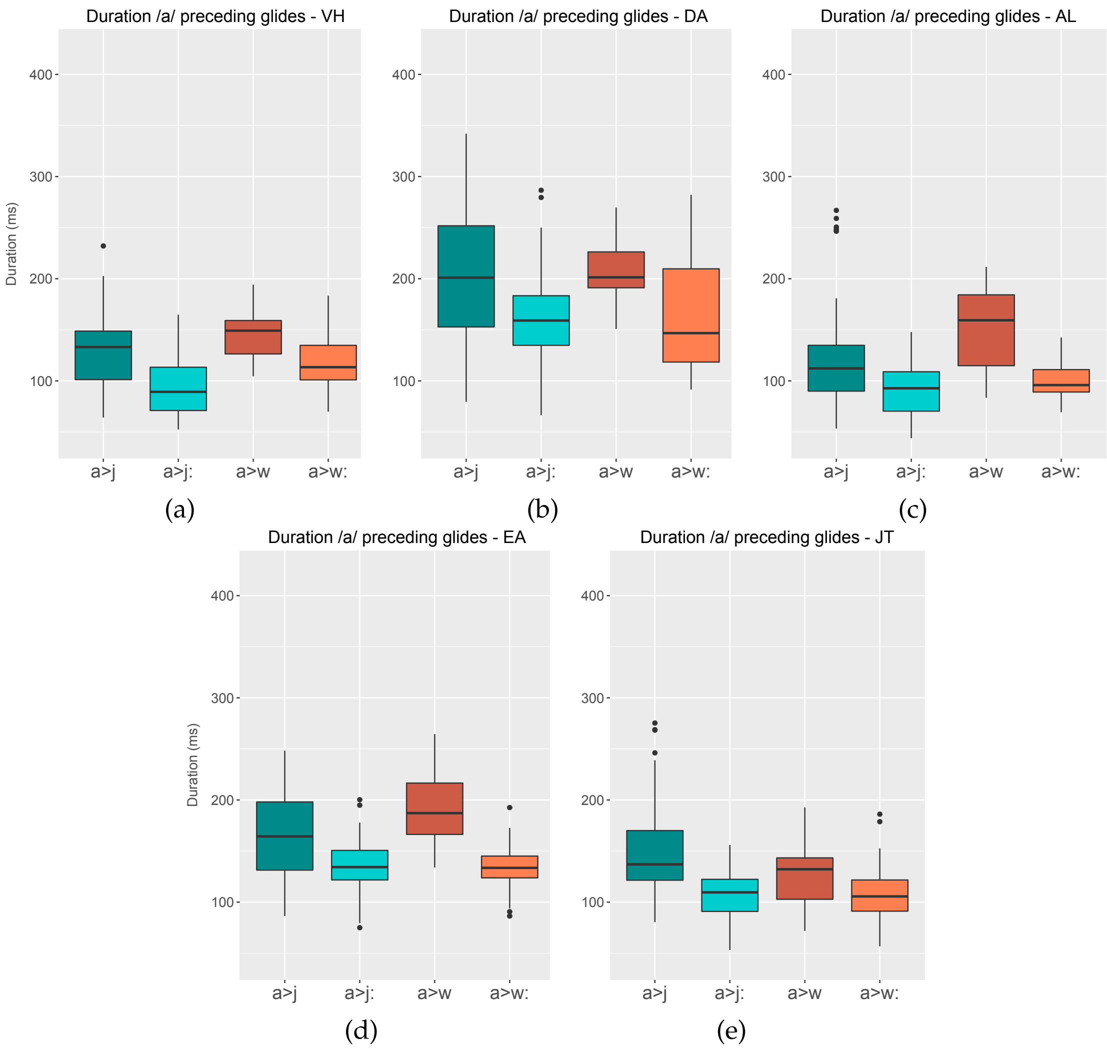


Figure 5.4: *Duration (ms) of /a/ preceding singleton and geminate glides, for each participant.*

Table 5.5: *Results of Tukey's post-hoc tests for comparisons between glides for F1, F2 and F3 values at glide midpoints (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

Glide formant values comparison	F1 result	F2 result	F3 result
/jː/ ∼ /j/	***	***	***
/wː/ ∼ /w/	***	**	-
/jː/ ∼ /w/	***	***	***
/wː/ ∼ /j/	***	***	-
/jː/ ∼ /wː/	*	***	***
/w/ ∼ /j/	-	***	**

5.5.2 Spectral properties of glides

5.5.2.1 F1

Figure 5.5 shows plotted midpoint values for the first and second formant frequencies of each /wː, w, jː and j/ token. Formant trajectories for the palatal glides are shown in Figure 5.6, and for the labial-velar glides in Figure 5.7. There are clear differences in the first formant characteristics of geminate compared to singleton glides, with geminate glides showing lower first formant values, indicative of a closer quality. It is also notable that the ellipses showing 95% confidence intervals tend to be much smaller for the geminate glides, while the singletons are much more variable, particularly in terms of F1 values, suggesting that the singleton glides are both more open but also perhaps more affected by the formant characteristics of neighbouring vowels. The likelihood ratio test for F1 data is significant (χ^2(3, N=2384) = 20.63, p<0.001), and post-hoc tests, summarised in Table 5.5, show a number of significant differences. F1 values for /wː/ are significantly lower than for /w/ by an estimated 136 ± 17 Hz, and also lower than for /j/ by 135 ± 16 Hz. F1 values for /jː/ are significantly lower than for /j/ by 165 ± 14 Hz, and similarly lower than for /w/ by 166 ± 16 Hz. Singletons /w/ and /j/ do not differ significantly in terms of F1 (p=0.100), but there is a small F1 difference of an estimated 30 ± 10 Hz between geminates /wː/ and /jː/ (p<0.05).

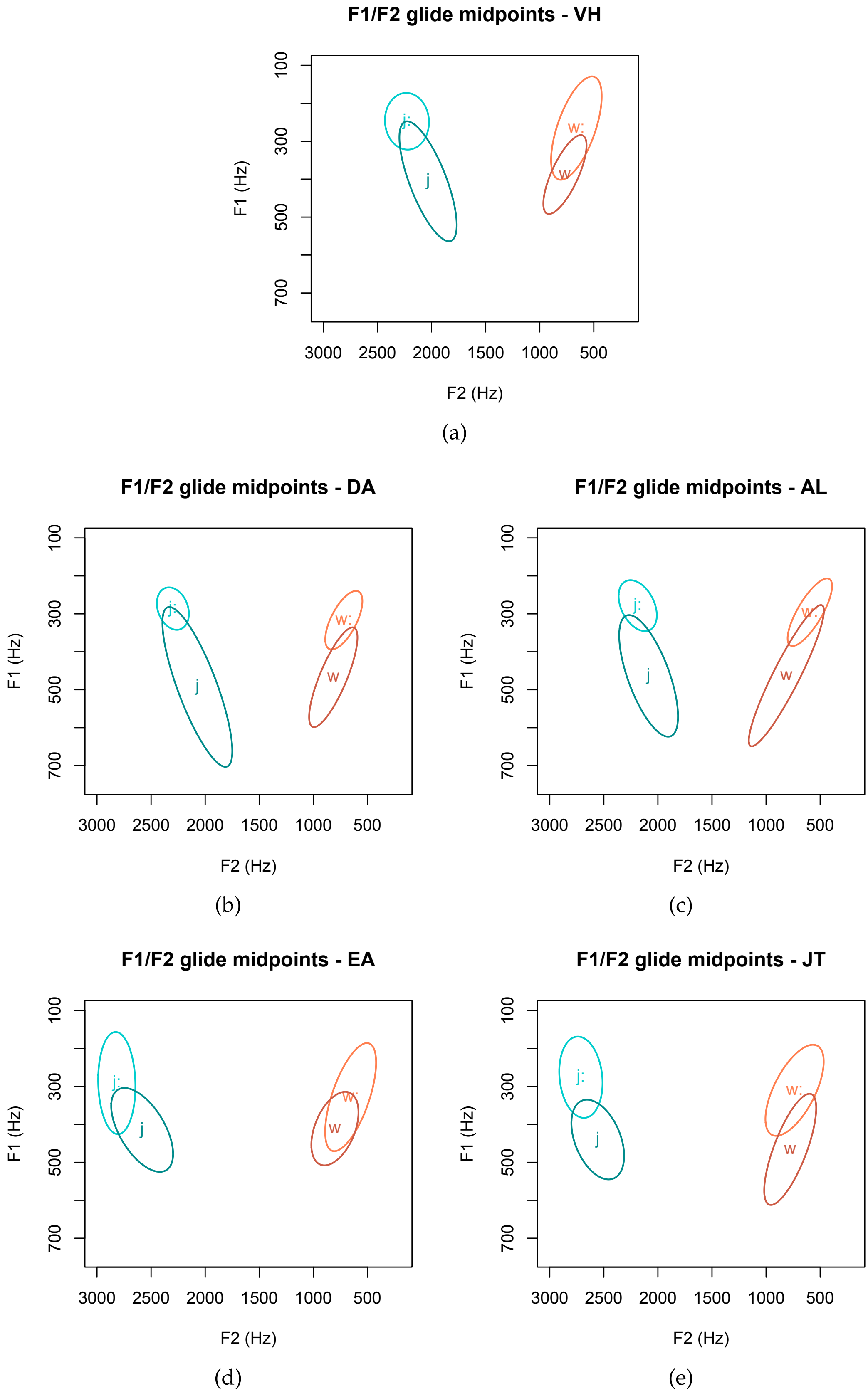


Figure 5.5: *First and second formant frequencies (Hz) at midpoints of singleton and geminate glides, for each participant (95% confidence intervals).*

5.5.2.2 F2

The midpoint plots in Figure 5.5 and trajectory plots in Figure 5.6 and Figure 5.7 also show some differences in the second formant frequencies of /wː, w, jː and j/. Given that the palatal and labial-velar glides correspond to different places of articulation, differences in F2 are of course expected for comparisons between them, but there are also observable differences between the singleton/geminate pairs. The geminate palatal glides tend towards higher F2 values than their singleton counterparts, while the geminate labial-velar glides tend towards lower F2 values than their singleton counterparts. The likelihood ratio test for F2 data indicates that glide category does have a significant effect ($\chi^2(3, N=2384) = 21.446$, $p<0.001$). Statistical results for post-hoc tests on second formant frequencies are summarised in Table 5.5, and reveal significant differences between all pairs in this comparison. F2 values for /wː/ are significantly lower than for /w/ by an estimated 122 $\pm$ 35 Hz, and, as expected given the different places of articulation, lower than for /j/ by 1580 $\pm$ 117 Hz. F2 values for /jː/ are significantly higher than for /j/ by 192 $\pm$ 27 Hz, and, again due to place of articulation differences, higher than for /w/ by 1651 $\pm$ 134 Hz. Singletons /w/ and /j/ unsurprisingly differ in terms of F2, with /w/ having values 1459 $\pm$ 124 Hz lower than /j/, and a similar but larger difference between the two geminates, with /wː/ having F2 values 1773 $\pm$ 124 Hz lower than /jː/.

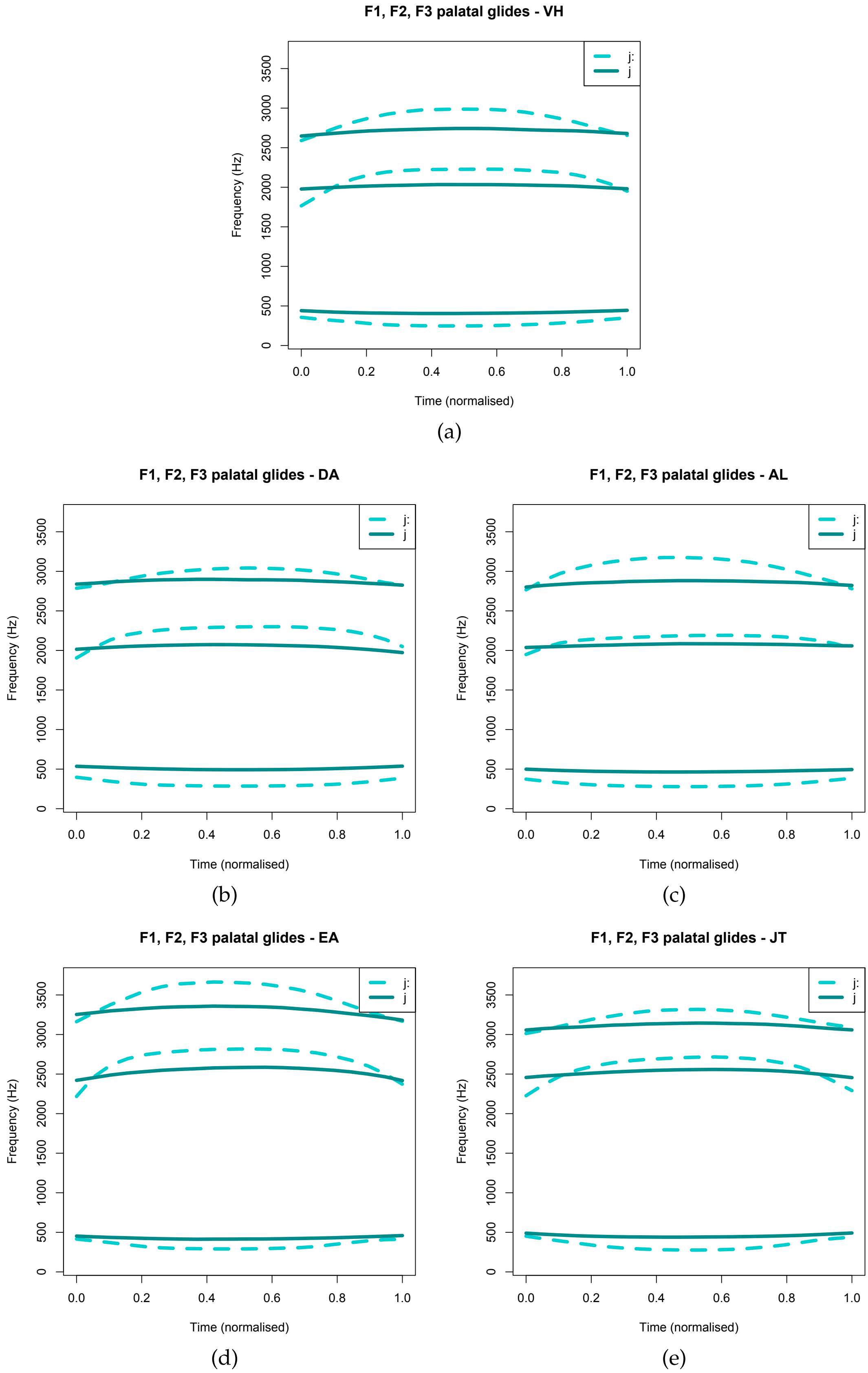


Figure 5.6: *Time-normalised F1, F2 and F3 trajectories (Hz) for palatal glides, for each participant.*

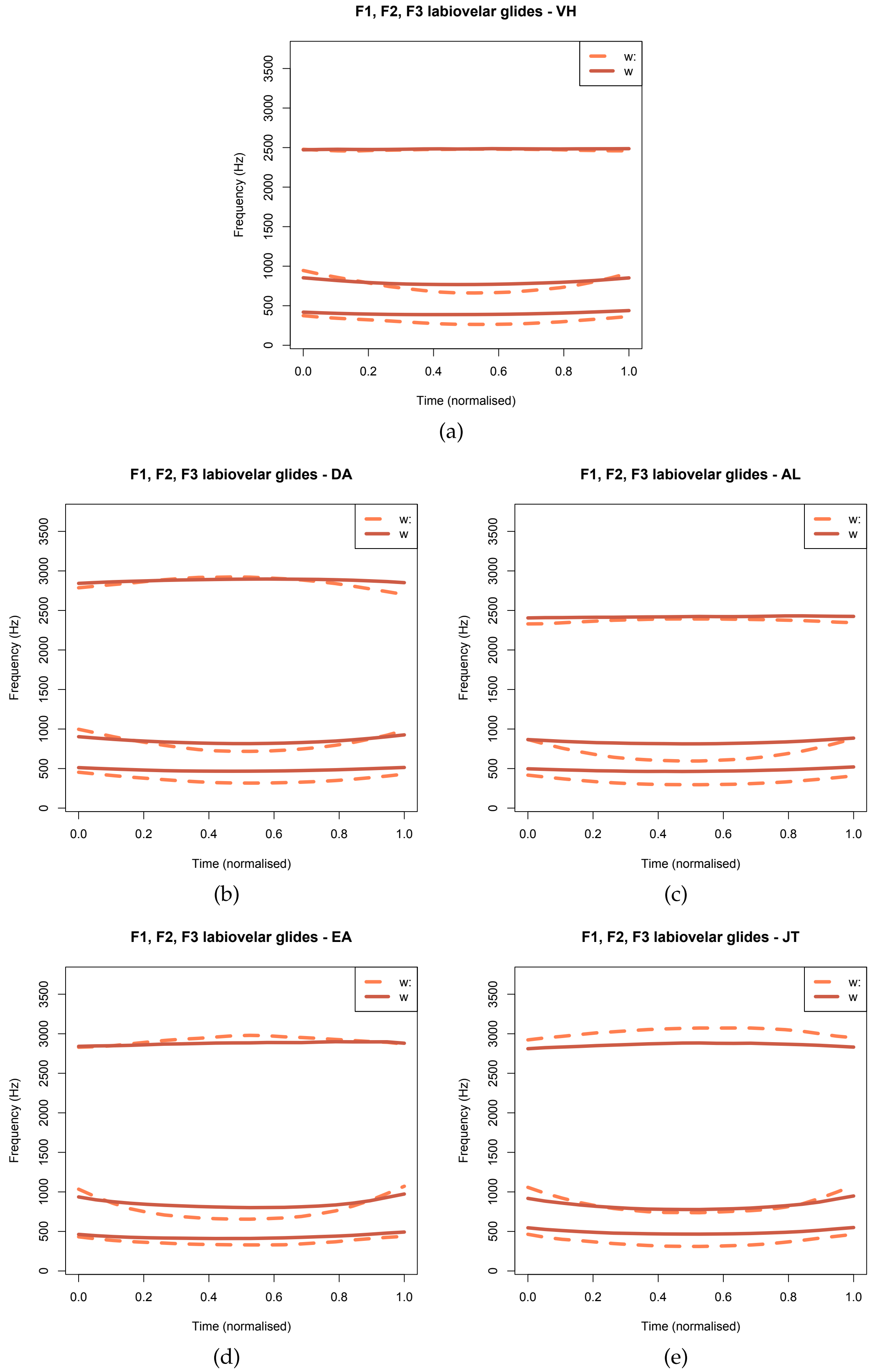


Figure 5.7: *Time-normalised F1, F2 and F3 trajectories (Hz) for labial-velar glides, for each participant.*

5.5.2.3 F3

Figure 5.8 shows third and second formant frequencies for /wː, w, jː and j/, taken at the midpoint of each glide token, and, as for F1 and F2, the full trajectories of palatal and labial-velar glides can be seen in Figure 5.6 and Figure 5.7 respectively. In both the trajectories in Figure 5.7, and midpoint plots in Figure 5.8, there appears to be little difference between the singleton and geminate labial-velar glides in terms of F3. The likelihood ratio test is significant ($\chi^2(3, N=2384) = 18.65$, $p<0.001$), suggesting that glide category influences F3 values, but the post-hoc tests, summarised in Table 5.5, show that this depends on the place of articulation of the glide. Statistical results confirm that there are no significant differences between F3 values for /wː/ and for /w/ ($p=0.40$), while F3 differences for /wː/ compared to /j/ do not quite reach significance ($p=0.05$). F3 values for /jː/ are significantly higher than for /j/ by 237 $\pm$ 35 Hz, and, due to place of articulation differences, higher than for /w/ by 521 $\pm$ 113 Hz. Singletons /w/ and /j/ differ in terms of F3, with /w/ having values 285 $\pm$ 84 Hz lower than /j/, and a similar but larger difference between the two geminates, with /wː/ having F3 values 466 $\pm$ 126 Hz lower than /jː/.

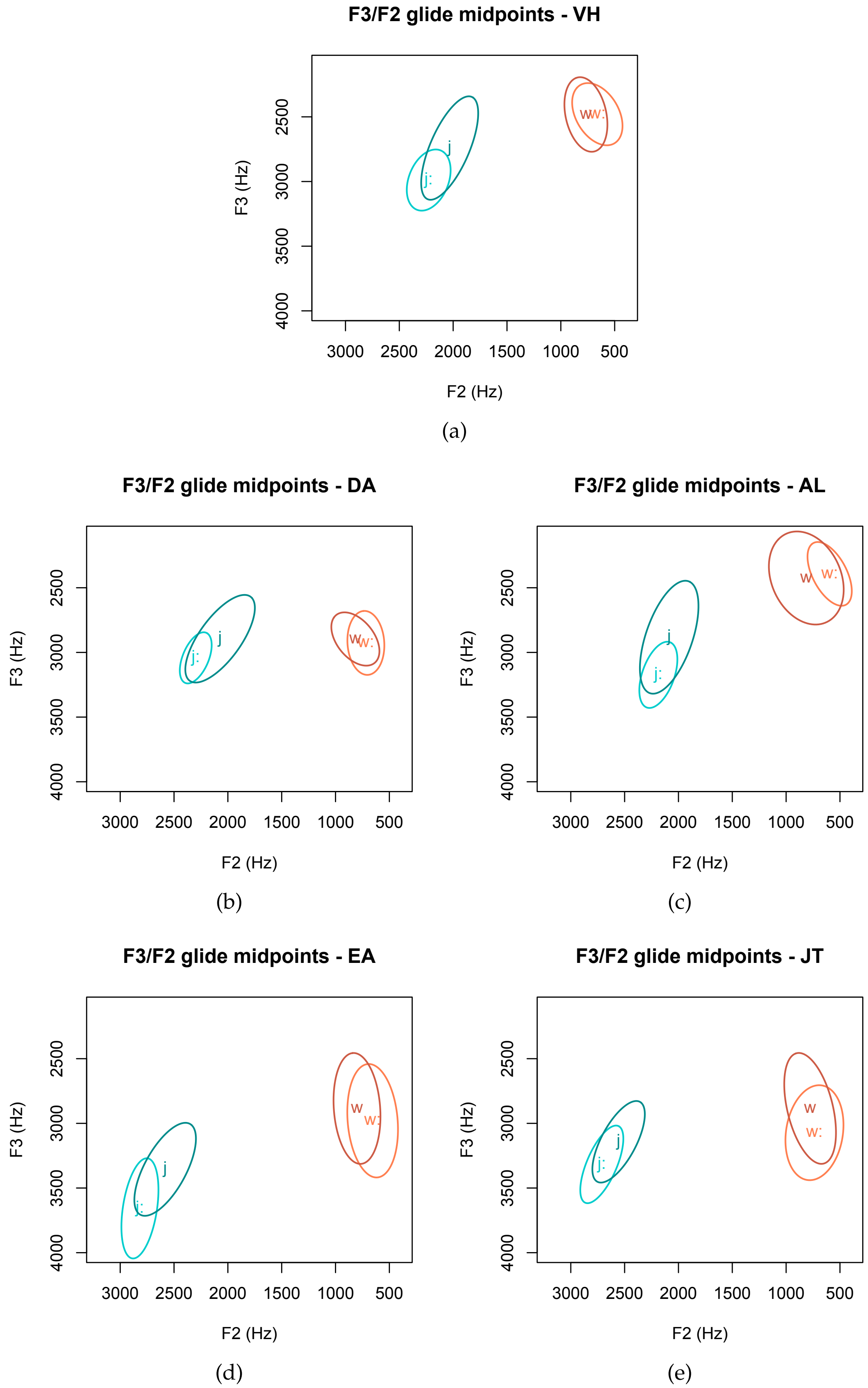


Figure 5.8: *Second and third formant frequencies (Hz) at midpoints of singleton and geminate glides, for each participant (95% confidence intervals).*

5.5.2.4 F1/F2 for /a/ preceding glides

To investigate whether the observed formant differences between geminate and singleton glides are anticipated in preceding vowels, as some impressionistic remarks suggest, the subset of 1,055 tokens of /a/ preceding glides was again used. Figure 5.9 shows plotted values for the first and second formant frequencies of /a/ tokens preceding /wː, w, jː and j/, and indicates that there are some formant differences for /a/ depending on which glide follows.

The likelihood ratio test for F1 values is significant ($\chi^2(3, N=1,055) = 11.70, p<0.01$), and post-hoc tests, summarised in Table 5.6, show significant differences between vowels in different glide contexts. Open vowels preceding /wː/ have F1 values significantly lower than those preceding /w/ by an estimated 81 $\pm$ 24 Hz, and similarly lower than those preceding /j/ by an estimated 76 $\pm$ 24 Hz. F1 values for open vowels preceding /jː/ are an estimated 74 $\pm$ 17 Hz lower than for those preceding /j/ and an estimated 79 $\pm$ 18 Hz lower than for those preceding /w/. There are no significant differences between /a/ tokens preceding /wː/ and /jː/ (p=1.00), or /w/ and /j/ (p=0.99).

For F2 values, the likelihood ratio test is also significant ($\chi^2(3, N=1,055) = 70.19$, $p<0.001$), but post-hoc tests reveal no significant differences between open vowels preceding singleton and geminate glides at the same place of articulation, though the difference between /wː/ and /w/ approaches significance (p=0.07). Instead, significant results are obtained between open vowels preceding palatal compared to labial-velar glides; F2 values are higher for open vowels preceding /jː/ than /wː/ by an estimated 206 $\pm$ 32 Hz, and higher by 295 $\pm$ 36 Hz preceding /w/, and F2 values for /a/ preceding /j/ are higher than before /wː/ by an estimated 246 $\pm$ 39 Hz, and than before /w/ by 334 $\pm$ 36 Hz.

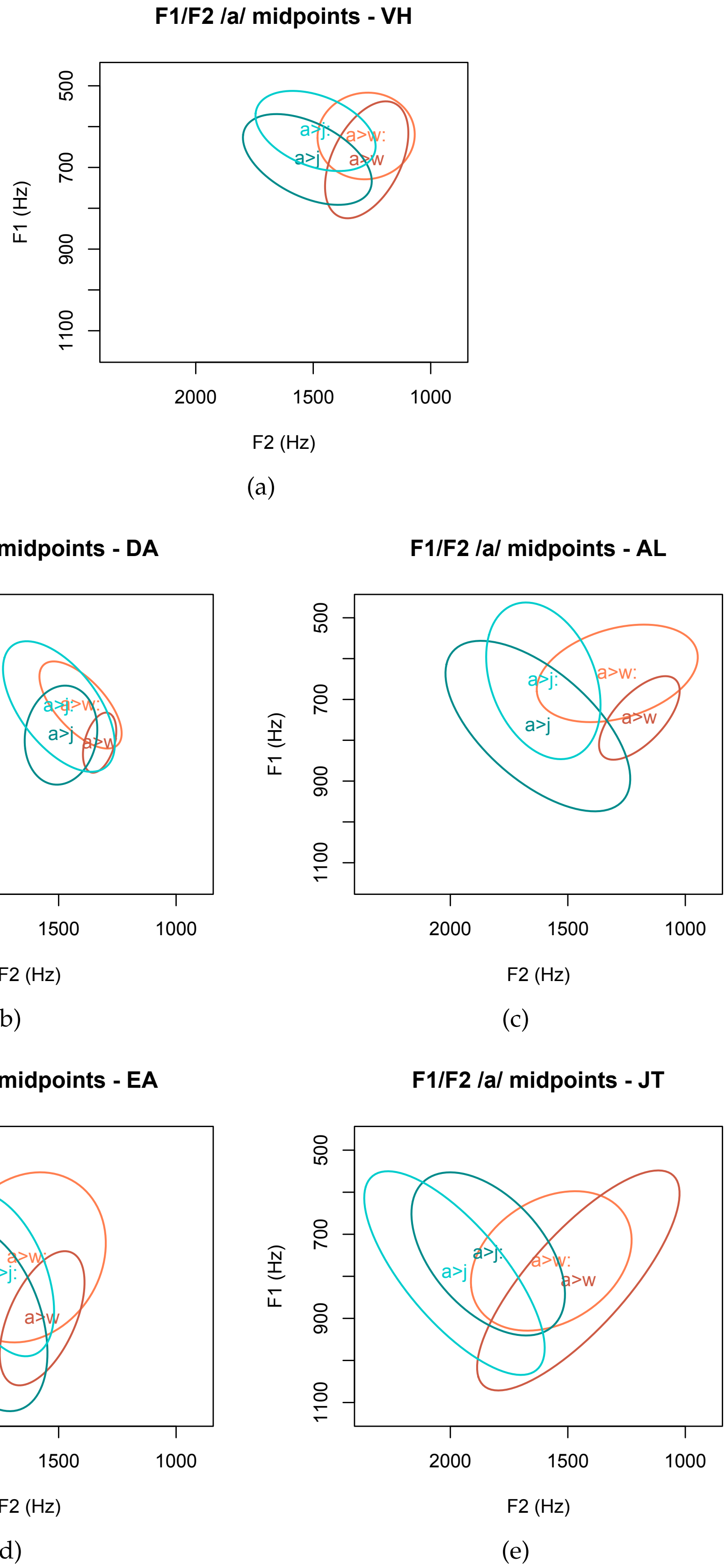


Figure 5.9: *First and second formant frequencies (Hz) at midpoints of /a/ tokens preceding singleton and geminate glides, for each participant (95% confidence intervals).*

Table 5.6: *Results of Tukey's post-hoc tests for comparisons between /a/ tokens preceding glides for F1/F2 values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

Vowel F1/F2 comparison	result F1	result F2
/a/ before /jː/ ∼ /a/ before /j/	***	-
/a/ before /wː/ ∼ /a/ before /w/	**	-
/a/ before /jː/ ∼ /a/ before /w/	***	***
/a/ before /wː/ ∼ /a/ before /j/	**	***
/a/ before /jː/ ∼ /a/ before /wː/	-	***
/a/ before /w/ ∼ /a/ before /j/	-	***

5.5.3 Intensity

5.5.3.1 Intensity of glides

Figure 5.10 shows intensity data taken from midpoints of /wː, w, jː, j/ tokens. A tendency towards lower dB-RMS values is apparent for the geminate glides compared to the singleton glides. The likelihood ratio test for intensity data is significant (χ^2(3, N=2384)= 79.33, p<0.001), suggesting that glide category has an effect. A summary of the post-hoc tests is shown in Table 5.7. These reveal that there are significant intensity differences between midpoints of /wː/ and /w/. /wː/ has values 3 ± 0.4 dB lower than /w/, and also has values 3 ± 0.4 dB lower than for /j/. Similarly, intensity values for /jː/ are significantly lower than for /j/ by 3 ± 0.4 dB, and significantly lower than for /w/ by 3 ± 0.4 dB. There are no significant intensity differences between singletons /w/ and /j/ (p=0.98), nor between geminates /wː/ and /jː/ (p=1.00).

Table 5.7: *Results of Tukey's post-hoc tests for comparisons between glides for intensity values at glide midpoints, and at glide midpoints relative to the midpoint of the preceding vowel. (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

Glide intensity comparison	result dB	result relative dB
/jː/ ∼ /j/	***	***
/wː/ ∼ /w/	***	***
/jː/ ∼ /w/	***	***
/wː/ ∼ /j/	***	***
/jː/ ∼ /wː/	-	
/w/ ∼ /j/	-	

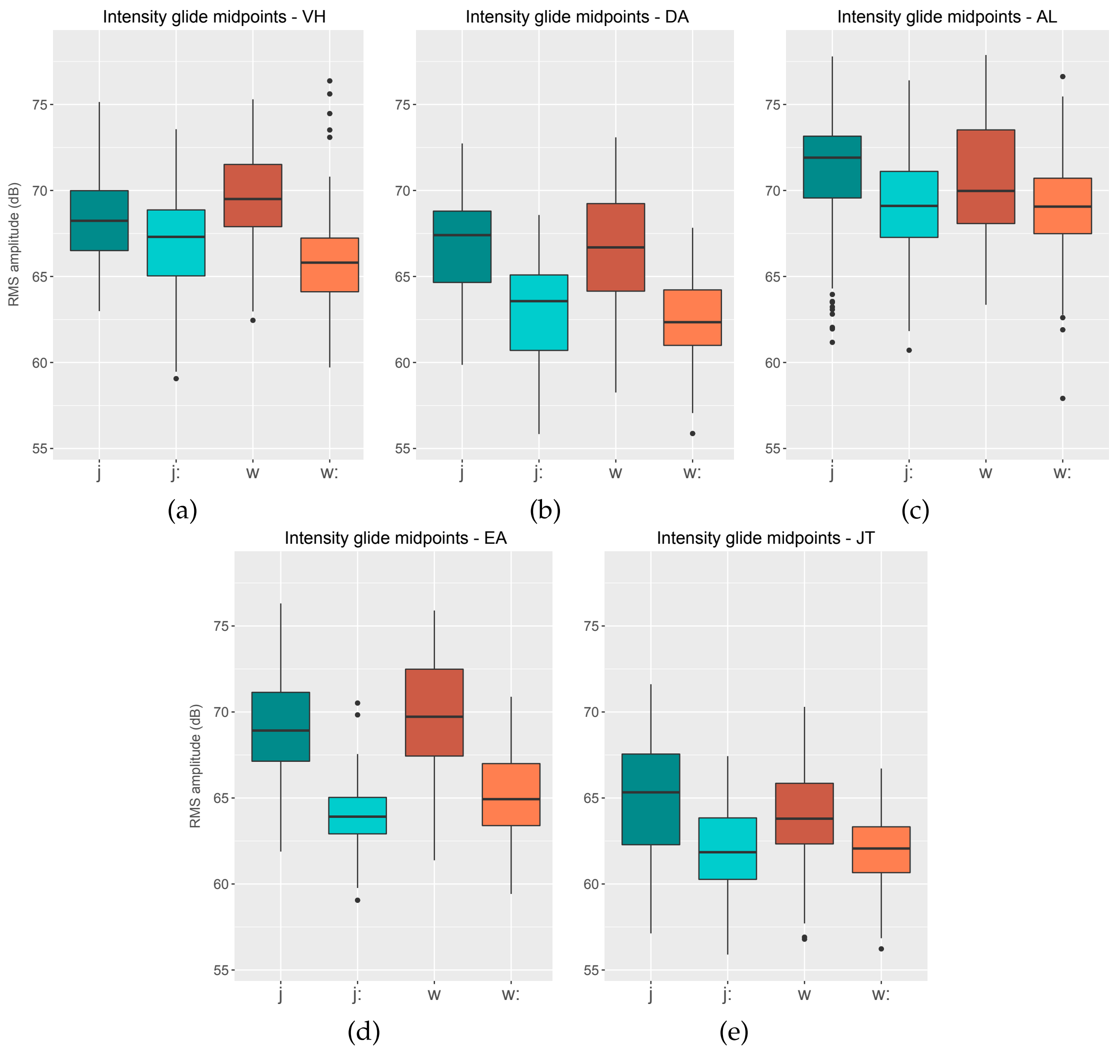


Figure 5.10: *Intensity (dB-RMS) at midpoints of singleton and geminate glides, for each participant.*

5.5.3.2 Intensity differences between glides and preceding vowels

Figure 5.11 shows the difference between intensity values taken from the midpoints of vowels preceding glides, and intensity values taken from the midpoints of /wː, w, jː and j/ tokens, as a measure of how large the drop in intensity is for different glides. A tendency towards higher dB-RMS values is apparent for the geminate glides compared to the singleton glides. The likelihood ratio test for intensity data is significant (χ^2(3, N=2384)= 75.17, p<0.001), suggesting that glide category has an effect. A summary of the post-hoc tests is shown in Table 5.7.

These reveal that there are significant differences in the size of the intensity drop for different glides, compared to the vowels preceding them. For /wː/, there is a significantly larger drop in intensity than for /w/, by an estimated 3 $\pm$ 0.5 dB. /wː/ also shows a drop an estimated 4 $\pm$ 0.5 dB larger than for /j/. For /jː/, there is a significantly larger drop in intensity than for /j/, by an estimated 3 $\pm$ 0.5 dB, and a similar difference in intensity for /jː/ compared to /w/, larger by 3 $\pm$ 0.5 dB. There are no significant differences in relative intensity between singletons /w/ and /j/ (p=0.66), nor between geminates /wː/ and /jː/ (p=0.64).

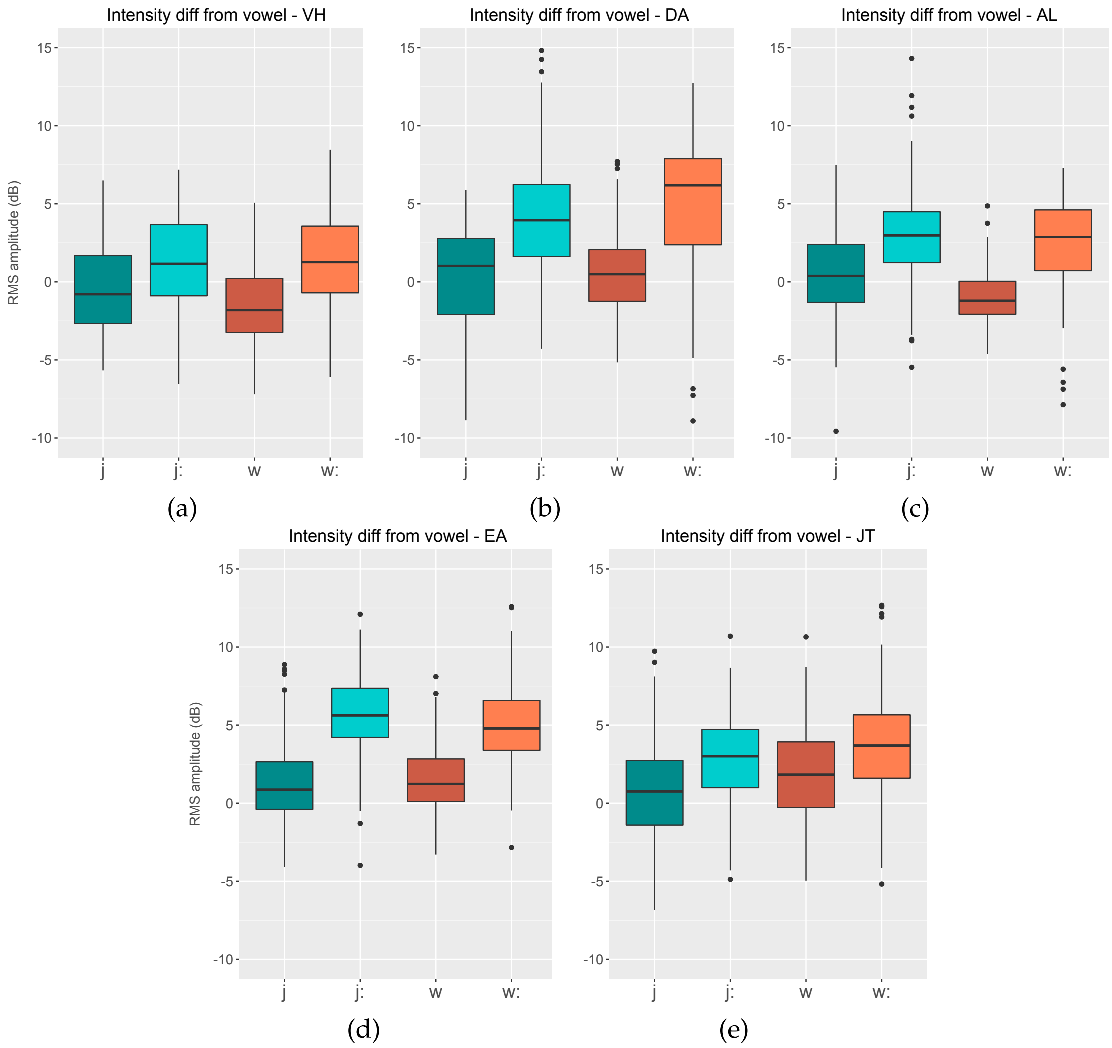


Figure 5.11: *Intensity difference (dB-RMS) between midpoints of singleton and geminate glides and midpoints of preceding vowels, for each participant.*

5.6 Discussion

5.6.1 Durational correlates of glide categories

The broad goal of this chapter was to establish the evidence for, and nature of, contrasts among glides in Lopit, in relation to Research Question 4: "What are the phonetic characteristics of contrastive glides in Lopit?" Drawing on existing literature pertaining to the phonetics of glides and geminates, and the segmental patterns proposed for Lopit and related languages, three hypotheses were put forward for testing. The first hypothesis, given in 5.3, focuses on both the evidence for contrasts between glides in Lopit, and the appropriateness of describing the proposed contrast as one of length: "Lopit has four contrastive glides: labial-velar /w, wː/ and palatal /j, jː/. /wː/ and /jː/ can be characterised as geminate glides, and are distinguished from /w/ and /j/ by higher duration values."

Overall, data presented in 5.5 provide strong phonetic evidence for four contrastive glides, and build on the phonological analyses put forward in Chapter 3. Results of particular relevance to this first hypothesis are those presented in 5.5.1.1, showing the constriction duration values for each glide. These suggest that a phonological analysis based on length is plausible for pairs of Lopit glides at the same place of articulation. There are substantial and significant differences in duration between proposed singletons and proposed geminates, with /wː/ being 1.71 times longer than /w/, and /jː/ being 1.82 times longer than /j/. Furthermore, singletons /w/ and /j/ are durationally similar to one another, and geminates /wː/ and /jː/ are also durationally similar to one another, suggesting that the glides at different places of articulation are subject to a shared pattern. These duration results fit with the impressions of length differences noted by other authors discussing Lopit glides (Vossen, 1982; Turner, 2001; Stirtz, 2014b), and also accord with the findings of crosslinguistic overviews that duration is the most consistent phonetic correlate of proposed singleton/geminate contrasts (Ridouane, 2010; Hamzah, 2013; Kawahara, 2015). The ratio is fairly typical of consonantal length contrasts, for which geminates tend to be 1.5–3 time longer than singletons (Ladefoged & Maddieson, 1996b). It is perhaps at the higher end of the very small number of examples provided for singleton/geminate glides in research on other languages, discussed in 5.2.5. More generally, the data presented here provide further support for arguments by Maddieson (2008) that glides can indeed occur geminated in the world's languages, despite short durations being often considered an inherent characteristic of glides, and show that duration differences can be reliably observed despite glides being considered suboptimal hosts for length contrasts (Kawahara, 2007). Though glides are argued to be dispreferred as geminates for reasons of perception rather than production (Kawahara, 2007), some researchers have suggested that for languages with length contrasts at all manners of articulation, glide length will be less clearly signaled, as evidenced by smaller duration ratios for glides, and more overlap in duration values (Aoyama, 2005; Aoyama & Reid, 2006) (though other studies have found little difference, at least in ratios (Kawahara, 2007)). While the present experiment does not make any comparisons across manners of articulation, it is clear that at least in terms of production, the duration difference between these singleton and geminate glides is robust, with high ratios and little overlap in the distribution of duration values.

A second hypothesis was also concerned with duration values, in this case for vowels preceding each glide, as presented in 5.5.1.2. Results show that in addition to observed differences in the durations of glides themselves, there is also a tendency for vowels preceding geminate glides to be have lower duration values than vowels preceding singletons. This accords with findings in many other languages with geminate segments (see e.g. overviews in Ridouane, 2010; Hamzah, 2013; Kawahara, 2015), though very little evidence of this sort has been reported specifically for glides. When looking at the durations of all vowels preceding glides in the present Lopit data, vowels preceding /jː/ are significantly shorter than those preceding /j/, and vowels before /wː/ are significantly shorter than those before /w/. When looking at a subset of the data only including tokens of /a/ as the preceding vowel, to minimise possible duration differences due to varying vowel qualities, differences are again significant between both /jː/ and /j/ and /wː/ and /w/. These results indicate that pre-geminate vowels in Lopit likely behave similarly to pre-geminate vowels in many other languages, and are realised with shorter duration values. Pre-geminate vowels in Lopit do not seem to be realised with no difference in duration values compared to pre-singleton vowels, as in Egyptian Arabic (Kawahara, 2007), and the data do not show any sign of trend for longer pre-geminate vowels, as in Japanese (Idemaru & Guion-Anderson, 2009).

To my knowledge, these phonetic results are the first pertaining to glide contrasts in Eastern Nilotic, and point towards the value in further investigating glides in related languages with similar attested contrasts, particularly given the tentative proposals that geminate glides in Eastern Nilotic may have a common origin. Current hypotheses regarding the origin of these glides are highly speculative, and hampered by the lack of detailed crosslinguistic data, but include suggestions that at least the labial-velar geminate glides may have arisen from sequences of velar or bilabial consonants followed by glides (Vossen, 1982, pp. 249–252; Dimmendaal, 1983b, p. 14). It would not be surprising for original sequence of stops followed by glides to have, as reflexes, segments which are phonologically long (Blevins, 2008), but as noted earlier, it is not entirely clear that length is the most salient feature of the contrast across other Eastern Nilotic languages. It is also not clear whether other geminate/singleton contrasts attested in Lopit and some related languages, such as the contrast between /tː/ and /t/, arose via similar mechanisms. While the languages in the immediate Lotuxo family have some geminate/singleton contrasts beyond glides, for the most part these don't appear to be present elsewhere in Eastern Nilotic. In ongoing work, it will be fruitful to examine the duration characteristics of these other segments, and the vowels preceding them, to see whether the durational tendencies observed for glides can be considered part of a pattern applying across consonant types. Furthermore, given that both the singleton and geminate glides in Lopit can occur word-initially, as can other consonants with proposed length contrasts, it will be of interest to see how, or whether, length contrasts are maintained in initial position. Future work in this area would offer valuable insights into both the gemination of glides and into word-initial gemination, both of which are much less well understood than more typologically common phenomena such as the gemination of intervocalic obstruents.

5.6.2 Other acoustic correlates of glide categories

The third hypothesis, based on remarks made by other authors, and early impressions in the wider present study, was that “In addition to duration, phonetic cues including lower first formant frequencies and lower RMS amplitude differentiate Lopit /wː/ and /jː/ from their counterparts /w/ and j/ respectively, and furthermore, evidence for lower first formant frequencies will be apparent in vowels preceding geminate glides.” Data presented in 5.5 indicate that there are indeed other phonetic correlates of the proposed contrast, in addition to duration. Measures investigated in relation to this hypothesis were F1, F2 and F3 of glides, and F1 and F2 of some vowels preceding glides, with results presented in 5.5.2, as well as the intensity of glides, and glides relative to preceding vowels, with RMS amplitude results shown in 5.5.3.

The data show that in Lopit, geminate glides have significantly lower intensity values compared to singletons, based on measures of root mean square amplitude taken at the glide midpoint. The estimated difference between /wː/ and ipa/w/, and /jː/ and /j/, is in the realm of 3dB. Similar values, around 3–4dB, are obtained when looking at the size of the drop in intensity for geminates /wː, jː/ and singletons /w, j/ relative to the intensity of the vowel preceding them. Given that many vowels preceding geminates in this dataset are word-initial, with amplitude often still rising at the midpoint, this drop would likely be larger with more non-initial vowels in the sample. The intensity drop is particularly interesting given arguments that sonorants, especially glides, are crosslinguistically dispreferred for gemination by virtue of their high sonority; their vowel-like nature is thought to make the boundaries between sonorants and vowels less clearly demarcated, and therefore make it more difficult for listeners to accurately perceive constriction duration (Podesva 2002, cited in Dmitrieva, 2012; Kawahara, 2007). However, while the sonority of glides as a class is not disputed, the actual differences in sonority between singleton and geminate glides have rarely been investigated. Across other manners of articulation, studies show a greater drop in amplitude or intensity for geminate consonants compared to singletons (relative to the preceding vowel), but for glides, the amplitude differences between singletons and geminates may be very small, as in in Egyptian Arabic (Kawahara, 2007), or may show significant differences in the same way as for other consonants, for example in Persian (Hansen, 2012; Hansen & Myers, 2017). Intensity results for Lopit glides accord with the general tendency of geminates to have lower intensity than singletons, and suggest that although glides are high sonority, it is their sonority relative to each other which should be examined. This study provides some useful evidence pertaining to arguments put forward by Kawahara (2007) and others. If glide duration is difficult to perceive accurately due to high sonority, it makes sense for speakers of a language to use additional strategies to differentiate glides, and in particular to provide listeners with more easily identifiable cues to segment boundaries in relation to flanking vowels. Other research has established that glides in general are distinguished from vowels, including phonetically similar close vowels, partly by lower intensity, associated with greater constriction (Hunt, 2009); if two very similar glides exist in a language, it would not be surprising if similar strategies are exploited to make one even less vowel-like.

These findings for intensity are likely related to observations for formant frequencies, which may offer supplementary cues of a different sort. Results for F1 at glide midpoints show geminates /wː/ and /jː/ to have frequencies significantly lower than for /w/ and /j/, by approximately 135–160Hz, indicating a closer quality. F2 results show /wː/ and /jː/ to have frequencies differing from /w/ and /j/ by around 120–190Hz; F2 values are lower for /wː/ compared to /w/, and higher for /jː/ compared to /j/. F3 differences were only significant for /jː/ compared to /j/. Taken together, the F1 and F2 results suggest that the geminate glides are more peripheral than the singletons. The frequency data point towards a difference in the degree of constriction for the glides, and specifically a much narrower constriction for geminate glides, with concomitant effects on both formants and intensity. This provides an intriguing connection to remarks by Tucker and Bryan (1966, p. 448) that long/strong glides in Maasai belong to the ‘close’ category of sounds, while the short/weak glides can be characterised as ‘open’, and comments by Levergood (1987, p. 18) that ‘strong’ glides in the Arusa variety of Maa are, as well as long, “more approximated than in English”, while the ‘weak’ glides are “not as approximated as in English”. Though a pattern of frication for geminate glides was not observed in the present study, impressions of this reported by Turner (2001) suggest an even narrower constriction, which could be associated with particular speakers, or perhaps speech styles. The possibility of gestural differences for the geminate compared to singleton glides clearly lends itself to an articulatory study (for example, using ultrasound tongue imaging). These results also raise the question of whether the articulatory gestures differentiating glides bear any relationship to those observed for [+ATR] compared to [-ATR] vowels in Chapter 4, a topic very worthy of further research.

Some phonological descriptions of Eastern Nilotic languages include observations of a connection between geminate glides and [+ATR] vowel qualities, at least to the extent that they often occur together, but it is not yet clear how the characteristics of vowels and glides interact. In 3.4.3.3, it was proposed that in Lopit, changes in vowel quality preceding geminate glides may instead be a process of localised coarticulation, operating separately to other phenomena such as ATR harmony. The F1/F2 results presented in 5.5.2 for pre-glide /a/ provide some support for this; midpoint F1 values for the open vowel are significantly lower when it precedes geminates than when it preceded singletons, suggesting that the greater constriction of the geminates is already being anticipated at this point.[11] This is not explainable by ATR patterns; as established in the previous chapter based on F1 midpoints and other measures, there is no evidence that /a/ has a [+ATR] counterpart. The acoustic findings here suggest that instead of the glide quality being determined by the category of surrounding vowels, as has been implied for Otuho, the situation is likely the other way around, at least immediately preceding glides in Lopit.

While duration is clearly a major correlate of glide category in Lopit, the additional acoustic correlates observed in this experiment suggest that the category of Lopit glides is likely identifiable by a bundle of cues. There is much potential for future work to examine the relative perceptual salience of these. As noted above, it may well be that if a contrast of this sort is indeed challenging for listeners, it is the combined effect of these cues which is crucial. More generally, however, these results accord with findings elsewhere that consonantal contrasts with duration as a major correlate do typically show evidence of additional correlates (e.g. E. Payne, 2005, 2006; Ridouane, 2007, 2010), and

[11] While not included here, tests at later points in the vowel show an increasing difference between tokens in each of the two contexts.

illustrate the necessity of exploring various measures to identify the strategies used by speakers of a language to create meaningful distinctions between sounds.

5.7 Chapter Summary

This chapter has investigated three hypotheses relating to Research Question 4, "What are the phonetic characteristics of contrastive glides in Lopit?". Strong evidence was found for all three. Measures of constriction duration for the four putative glides /w, wː, j, jː/ show that /wː, jː/ are substantially longer than /w, j/, and measures of preceding vowel duration show that vowels preceding /wː, jː/ are shorter, as is often noted for vowels preceding geminates in other languages. Furthermore, there are additional phonetic correlates to glide category; lower intensity values as well as lower first formant frequencies for /wː, jː/ compared to /w, j/ are indicative of a more constricted articulation, and /wː, jː/ could be described as more consonantal on the basis of these acoustic cues. Taken together, these findings provide robust evidence that in Lopit, there is a contrast between glides at the same place of articulation, with duration as a significant correlate. They also provide further phonetic insight into the nature of these typologically uncommon contrasts crosslinguistically, and suggest a number of future directions for investigating the open question of which cues listeners are most attentive to in the perception of these segmental differences, and for investigating the production of such contrasts in other languages, particularly related languages in the Nilotic family. In the the following chapter, Chapter 6, I turn from segmental to tonal phenomena, and investigate the phonetic evidence for the three tones (High, Low and Falling) proposed in Chapter 3.

Chapter 6

Acoustic Characteristics of Lopit Nominal Tone

6.1 Introduction

In the preceding two chapters, segmental phenomena of particular interest in Lopit were investigated using a range of phonetic measures. In Chapter 4, the acoustic and articulatory characteristics of Lopit monophthongs were explored, and evidence was provided for a 9-vowel system with an 'Advanced Tongue Root' contrast, with F1 as the primary acoustic correlate. In Chapter 5, the durational and acoustic properties of proposed singleton and geminate glides were examined, with results supporting impressions of a length contrast among glides, and evidence for additional formant and intensity cues to the contrast, indicative of a closer articulation for geminate glides. In this chapter, I turn to suprasegmental phenomena, specifically tone, which was identified in Chapter 2 and Chapter 3 as another area of Lopit phonology worthy of closer investigation. The content of this chapter addresses RQ5, "What are the phonetic characteristics of lexically contrastive tones on nouns in Lopit?". Some preliminary findings pertaining to this question have also been discussed in Billington (2015).

In Chapter 3, I presented evidence that the sound system of Lopit includes tonal contrasts used for both lexical and grammatical distinctions (3.5). Three contrastive tones were proposed: A High tone, a Low tone, and a Falling tone. Based on impressionistic observations, I suggested that the High and Low are level tones, distinguished by relatively high or low pitch, while the Falling tone transitions from high to low pitch. A tone inventory of this sort is fairly typical of Eastern Nilotic languages, but the proposals made here for Lopit differ slightly to observations in previous work (2.4.2). The major aim of this chapter is to test whether the observations of High, Low and Falling tones are supported by acoustic data, and relatedly, to examine how the realisation of these might vary in different tonal contexts. Of particular interest is whether findings for fundamental frequency, as the acoustic correlate of pitch, reveal consistent differences between proposed tone categories. Additional measures of duration and intensity are included, partly because of the potential for these to vary for different tone types, but also for the secondary aim of this chapter, which is to establish whether there are specific differences in how tones are realised in different tonal contexts. Some remarks from previous authors, discussed in 2.4.2, 3.5 and further below, suggest that these possible differences need to be taken into consideration in order to establish the contrasts.

I begin by drawing together relevant points from previous chapters relating to tone in Lopit and Eastern Nilotic languages, as well as African languages more generally, in 6.2, together with literature on the phonetic correlates of tone, in order to demonstrate the motivations for and approach to this experiment. Hypotheses regarding Lopit lexical tone are put forward in 6.3, and the methodological approach is explained in 6.4. Results are then presented in 6.5 according to each phonetic measure investigated, and discussion of these results in relation to each hypothesis follows in 6.6.

6.2 Background

6.2.1 Tone systems in African languages

A great many languages of Africa make use of tonal contrasts. As discussed in 2.4.1, these contrasts are very often drawn on to signal grammatical as well as lexical distinctions, a characteristic considered to be one of several that sets African tone systems apart from those found in languages of Asia (for which tone primarily has a lexical function). Other widely-discussed areal differences, for example in tone realisation, are discussed further below. The grammatical as well as lexical significance of tone has long been noted for Nilo-Saharan languages (Tucker & Bryan, 1966), including those within the Eastern Nilotic family, and many descriptions of individual languages emphasise that tone has a far greater grammatical than lexical functional load (e.g. Tucker & Mpaayei, 1955, p. 16; Rasmussen, 2002, pp. 22–24; Dimmendaal, 1983b, p. 36). However, among Nilo-Saharan languages, very few comprehensive descriptions of the grammatical functions of tone are available, including within the Eastern Nilotic family. Given that identifying grammatical uses of tone is inevitably tied to also identifying lexical uses of tone, and any processes affecting tone realisation (Hyman, 2013), the limited availability of comprehensive descriptions is partly related to the need for more research on the status of tones observed in individual languages.

As noted in 2.4.2, the tone systems of African languages are often described, following Pike (1948), as 'register systems', in which tonal distinctions are largely based on the relative pitch of a number of level tones (Clements & Rialland, 2008, pp. 70–74). It is suggested that two tone levels (typically high and low) are most common among African languages (Wedekind, 1985). 'Register systems' are held to differ from 'contour systems', in which changes in the shape of the pitch trajectory, in addition to multiple levels in the tonal space, are a crucial element of tonal distinctions. 'Contour systems' are attested in many languages of mainland southeast Asia (Yip, 1995). In such languages, contour tones such as rising or falling are generally assumed to be discrete units, and while contour tones are also found in many African languages, they are usually interpreted as sequences of e.g. high and low tones attached to a single tone-bearing unit. These regional associations are so strong that 'African tone' is often synonymous with 'register tone system' and '(East) Asian tone' with 'contour tone system', but, as noted in the original work by Pike (1948), there are many possibilities for languages which draw on elements of both canonical types (e.g. Evans, 2008; Hyman, 2010), and various other ways in which tone systems can be typologised (Hyman, 2001b, 2015). As shown in the overview in 2.4.2, striking diversity in tone systems can be found even just within the Nilotic language family.

Observations of common patterns in African tone systems are based on many detailed phonological analyses, predominantly for languages in the Niger-Congo phylum (e.g. Clements & Goldsmith, 1984). These analyses, particularly relating to tonal mobility and specific types of allophony, have made substantial contributions to phonological theory (Odden, 1995; Yip, 2002, pp. 130–170; Clements, 2000, pp. 152–158), and in particular to the development of autosegmental and metrical theory (Goldsmith, 1990). Contour tones in African languages often result from morphophonological processes which permit two level tones to simultaneously attach to a unit, or are variants of another tone in specific contexts, for example word-final realisations of a high tone (Yip, 2002, pp. 142–147; Clements & Rialland, 2008, p. 69). Even where such processes are not explicitly discussed, contours are generally described as sequences of level pitch targets. Odden (in press) writes that the evidence for decomposing contour tones into sequences of level tones attaching to a single tone-bearing unit is "so strong that the decomposition is typically taken for granted". However, various examples of African languages with phonemic contours can be found, including within the Nilotic family, for example in Western Nilotic Dinka (Remijsen, 2013) and Shilluk (Remijsen & Ayoker, 2014).

6.2.2 Observations on tone in Lopit

While the description of Lopit until recently was limited, there is clear agreement among authors that, as for other Nilotic languages (discussed in 2.4), Lopit phonology includes a set of tonal contrasts which are used to indicate both lexical and morphosyntactic distinctions (Vossen, 1982; Turner, 2001; Stirtz, 2014b). In 3.5, based on data collected in the current project, I presented phonological evidence for three lexically contrastive tones in Lopit: High, Low, and Falling. The syllable is proposed as the tone-bearing unit in the present study, as well as by Stirtz (2014b, p. 16). It was observed that true minimal pairs are uncommon, but do occur, though with the members often belonging to different word classes. Most often, there are segmental differences in addition to tonal differences, such as in the [ATR] quality of vowels in the word, or the presence compared to absence of a final glottal stop. All three tones occur freely with all [+ATR] and [-ATR] vowels and all syllable types. As shown in Table 3.9, the Falling tone occurs in all word positions, but it was noted to have a somewhat unbalanced distribution; at least among nouns, it is more common word-finally, and is rarely found adjacent to other High or Falling tones. It may occur adjacent to these more often among verbs, sometimes with grammatical significance, and can be observed when words are produced in a range of sentence contexts (initial, medial and final), as well as in isolation.

In ongoing and previous work, there are suggestions that in Lopit, tone has a relatively limited role in forming lexical contrasts (Turner, 2001, p. 44; Stirtz, 2014b, p. 16), but is crucial to indicating a range of grammatical distinctions (Moodie, in progress; Ladu, Nartisio, Bong, Odingo & Gilbert, 2014b), as noted above for Nilo-Saharan languages more generally. In Lopit, tone is particularly important in the verbal morphology, for example in aspectual marking (Moodie, in press), but its use appears to depend on the morphological sub-class of the verb, as well as the particular ways in which different grammatical uses of tone, as well as tone changes accompanying segmental morphemes, interact for different verbs. Data collection and analyses pertaining to these matters are ongoing, and much remains to be understood. The need for extensive linguistic description to take place before the range of morphosyntactic tonal alternations can be adequately understood and separated from lexical uses of tone, and from phonological processes affecting tone realisation, adds to the challenges of developing a comprehensive tonal analysis. Tone has a more limited role in Lopit nominal morphology; it is occasionally used for number-marking, but primarily for case-marking, and while the tonal patterns used to mark nominative case are quite lexicalised, as for number-marking patterns, the contexts in which they will or will not occur are quite predictable (Moodie & Billington, 2015). By virtue of being more accessible, nominal tone is also (somewhat) easier to control for in experimental elicitation, and this study therefore focuses on nominal data only.[1]

As shown in 2.4.2, tonal inventories comprising High, Low and Falling tones appear to be fairly typical of the Eastern Nilotic family, with some variation in the status of Falling tones. The observations of High, Falling and Low tones in Lopit are also broadly compatible with remarks in previous work discussed in 2.4 and 3.5, though there are some differences. Vossen (1982, p. 193), in his phonological observations for Dongotono, Lokoya and Lopit together, states that there are four tones, consisting of High, Low, Mid,

[1]Given that the grammatical description in Lopit is still in the early stages, and the lexical use of tone appears more limited, it may seem premature to conduct a phonetic experiment focusing on tonal contrasts. However, it is still useful to attempt to test some of the proposed lexical contrasts, and if the use of lexical tone is indeed limited, it will be interesting to see just how distinct the putative tone categories are.

and High-Falling. Turner (2001, p. 44) observes only two level tones, High and Low, plus a Falling tone, noting that Falling tones are uncommon in his transcribed data but also adding that he suspects that there are in reality more Falling tones than have been marked. Stirtz (2014b, p. 16) similarly observes two level tones, High and Low, as well as a Falling tone (analysed as a sequence of High and Low on one syllable), additionally noting that the Falling tone is common on word-final syllables, but rare in other word positions. Stirtz (2014b, p. 16) also notes the presence of a rare Rising tone. While the Rising tone is likely a notational variant arising from differing analyses of vowel phenomena (as discussed in 3.5 and 3.6), the Mid tones observed by Vossen (1982) may be allotones of High or Low tones, given that the accompanying transcribed wordlist data (Vossen, 1982, pp. 126–149) suggests that they tend to occur in particular tonal contexts. However, to date there have not yet been any phonetic explorations of tonal contrasts and variants in Lopit, and quantitative insights are similarly scarce for other Eastern Nilotic tone systems.

6.2.3 Tone and fundamental frequency

Canonical descriptions of tone, as a phonological property of languages, define it as the use of pitch in forming linguistic contrasts (e.g. Pike, 1948; Welmers, 1973, pp. 77–115; Yip, 2002, Hyman, 2015). In speech production, the percept of pitch is acoustically correlated with fundamental frequency, which has therefore been the main measure of interest in phonetic explorations of tonal contrasts (Ohala, 1978; Laver, 1994; Lehiste, 1970). A great many studies of languages spoken in mainland southeast Asia have demonstrated the significance of f0 differences between phonemic tones, such as for the Tai-Kadai language Thai (e.g. Abramson, 1962), the Sino-Tibetan language Mandarin (e.g. Howie, 1976), and the Austroasiatic language Vietnamese (e.g. Han & Kim, 1974). For these languages, which are typically described as having 'contour' systems, both the relative height as well as the shape of f0 trajectories are crucial to distinctions in tonal production and perception, including the timing of changes in the f0 trajectory (Shen & Lin, 1991). Further work has also identified language-specific assimilation and dissimilation processes applying to tones in different contexts (Han & Kim, 1974; Gandour, Potisuk

& Dechongkit, 1994; Xu, 1997). The tone systems of widely-spoken languages of this region are among the most well-described, particularly in terms of phonetic characteristics. Phonetic studies of languages in other regions, such as the Americas, have also confirmed correlations between tone and f0, such as for the Oto-Manguean language Itunyoso Trique (DiCanio, 2012a) and the Na-Dene language Tlingit (Maddieson, Smith & Bessell, 2001), and for some languages in regions such as New Guinea, for example the Skou language Vanimo (Donohue & van Vugt, 1992).

Though the distinctive use of tone is very common among languages of Africa, and observed patterns have significantly influenced phonological theory, as noted above, African languages are under-represented in phonetic investigations of tone (Pulleyblank & Allen, 2013). In part this is likely due to the combination of the analytical challenges posed by African tonal phenomena, and the limited available description for many languages. However, various analyses have been undertaken to investigate the relationship between fundamental frequency and proposed phonemic contrasts and phonological processes, for example for Niger-Congo languages including isiZulu (Govender, Barnard & Davel, 2005), Northern Sotho (Zerbian, 2009), Chichewa (Myers, 1999; Downing, 2016), Kinyarwanda (Myers, 2003), Yoruba (Connell & Ladd, 1990), Akan (Genzel, 2013; Kügler, 2016), Hausa (Lindau, 1986), Cambap (Connell, 2002), and Mambila (Connell, 2003, 2016). Little perception work has been undertaken, but some studies are available which provide evidence for the perceptual salience of pitch in at least some Niger-Congo languages (e.g. Connell, 2000). Languages of the Nilo-Saharan phylum have received less attention, but the relevance of fundamental frequency for tonal contrasts has been the subject of quantitative investigations for Kunama (Connell, Hayward & Ashkaba, 2000), a language isolate thought to be Nilo-Saharan, as well as a number of Nilotic languages. Most of these are languages of the Western Nilotic branch, such as Dinka (Remijsen, 2013) and Shilluk (Remijsen & Ayoker, 2014). Some explorations of tone and intonation have been undertaken for Eastern Nilotic Maa (Baltazani, 2002), but have so far not emerged for other Eastern (or Southern) Nilotic languages. In existing work on Lopit, there are no specific statements regarding the correlates of tones, but the assumption appears to be that tones are distinguished by pitch. Turner (2001, p. 47) reports some possible contextual variation, noting impressions that a tone early in a phonological phrase, perhaps the first high tone to occur, seems noticeably higher.

6.2.4 Other phonetic correlates of tone

However, other cues may also be present; work on various languages around the world has found some tones to have characteristic features of duration (perceived as length), intensity (perceived as loudness) and phonation type (perceived as voice quality) in addition to fundamental frequency. Inherent differences in tone duration have been noted for tones a number of languages, such as Mandarin (e.g. Xu, 1997), Cantonese (e.g. Kong, 1987), and Thai (e.g. Gandour, 1977). The results of individual phonetic and phonological studies together with crosslinguistic overviews point towards a tendency for contour tones to occur with longer duration values, either by only occurring in contexts which afford greater length, such as on long vowels, or by exhibiting lengthening of the rhyme compared to other tones (Gordon, 2001; Zhang, 2001). This may offer perceptual support for contour tone identification (S. Greenberg & Zee, 1979). For Lopit, Turner (2001, p. 44) comments on the possibility that some Lopit speakers may have impressions of vowels bearing falling tones as being slightly longer than those bearing level tones. While duration tendencies for level tones have been the subject of less crosslinguistic discussion, there are suggestions that low level tones may tend to be longer than high level tones (Faytak & Yu, 2011), though the opposite has also been observed (Zee, 1978). Particularly for level tones, it is not yet clear whether typological generalisations can be made confidently, given the limitations of available data; correlations between tone and duration may be language-specific. Timing may also be an important consideration in understanding tonal contrasts; beyond differences in f0 timing for contour tones with different shapes (discussed above) recent work on Western Nilotic languages Dinka (Remijsen, 2013) and Shilluk (Remijsen & Ayoker, 2014) provides evidence for contour tones which have similar trajectories in terms of f0 values but which are distinct based on the alignment of the fall.

In analyses of tone, there have been some observations of a close relationship between high fundamental frequency values and high intensity as indicated by RMS amplitude values, including evidence that RMS amplitude trajectories may follow similar patterns as for f0 trajectories in both level and contour tones, for example in Taiwanese (Zee, 1978) and Mandarin (Whalen & Xu, 1992; Fu & Zeng, 2000). For tones in some Bantu languages, correlations between f0 and intensity have also been observed (Zerbian & Barnard, 2008), and there is speculation that intensity may have a role in disambiguating some tones (Roux, 1995). However, the relationship is likely complex and mediated by various other factors, such as tonal and utterance context. Where correlations are found, it is not clear to what extent listeners may utilise these in tone identification. For example, while final Low tones in Yoruba differ from final Mid tones by having a lower (and falling) f0, as well as lower duration values and lower amplitude, modifications to duration and amplitude in a perception experiment did not cause a shift in tone identification judgments, whereas modifications to the f0 contour did (Hombert, 1976). However, in other experimental work, it has been shown that where f0 cues are absent, amplitude provides a substantial cue to tonal identification, for example for some Mandarin tones (Whalen & Xu, 1992; Fu & Zeng, 2000). In analyses of intonation in Eastern Nilotic Maa, Baltazani (2002) posited that amplitude provides cues to case-marking tones where the f0 characteristics of these are obscured by other intonation processes. No work of this sort has yet been undertaken for other Eastern Nilotic languages, but it is possible that such cues may have relevance elsewhere in the language family. Given that intensity is closely correlated with syllable prominence in many language varieties (e.g. Kochanski, Grabe, Coleman & Rosner, 2005), it is also possible that intensity is drawn on as a cue to metrical structure in Lopit, and interacts with the tone system. Patterns of this sort have been suggested for a number of African languages (Downing, 2004), and as discussed in 2.4.4, in several descriptions of Nilotic languages, researchers record their impressions of particular syllables being noticeably louder and/or longer than others, sometimes independently of tone.

In a number of languages for which fundamental frequency is considered to be the primary phonetic correlate of tone distinctions, some additional differences in laryngeal activity are noted. Observations of a characteristic creakiness occurring for one of several tones in varieties of Mandarin and Cantonese have been supported by acoustic and articulatory evidence, and have furthermore been shown to have perceptual salience for listeners (Davison, 1991; Yu, 2010; Yu & Lam, 2014). For some languages, co-occurrences of different pitch and phonatory characteristics are drawn on to a greater extent. A canonical example is Burmese, for which phonetic investigations have shown that cues including pitch, phonation, duration, and vowel quality interact to form contrasts between categories in the tonal system (Gruber, 2011; Kelly, 2012). For Burmese and other languages in which phonation and pitch distinctions do not operate independently of one another, these types of systems are also often referred to as 'register systems'. However, similar properties are also observed for languages which are traditionally described as tone rather than register systems, such as Northern Vietnamese (Brunelle, 2009; Brunelle, Nguyên & Nguyen, 2010) and Black Miao (Kuang, 2013a, 2013b). As Brunelle and Kirby (2016) argue, the enormous diversity (in terms of inventories and phonetic realisations) of tonal systems in Southeast Asia does not lend itself well to a clear demarcation between 'tone' and 'register' systems. Phonation differences are not usually discussed as a feature correlating with tone in African languages, but occasional mention of some possible correlations can be found, for example creakiness reportedly occurring with low tones in Yoruba (Welmers, 1973, p. 109).

6.3 Hypotheses

From the discussion in preceding sections of this chapter, and earlier in Chapter 2 and Chapter 3, several key points emerge for consideration in preliminary investigations of tone realisation in Lopit. These underpin the approach to Research Question 5, which is the focus of this chapter: "What are the phonetic characteristics of lexically contrastive tones on nouns in Lopit?" Two hypotheses were developed for testing in this experiment; the motivations behind these are discussed below.

A lexical (and grammatical) contrast between three tones (High, Low, and Falling) was proposed in 3.5 based on phonological analyses of Lopit language data. The same three tone categories are noted by other authors in discussions of Lopit phonology (Vossen, 1982; Turner, 2001; Stirtz, 2014b) (with some possible additions, returned to below). Impressionistic observations are that the High and Low tones are level tones, distinguished by relatively High or Low pitch, while the Falling tone is a contour tone beginning with a high pitch target before falling to a low pitch target. As the acoustic correlate of pitch, fundamental frequency has been show to distinguish tone categories in many languages around the world. Previous impressions of Lopit tone also include speculation that the Falling tone may be longer in duration (Turner, 2001). Duration differences between tones are sometimes noted where these have been measured in other phonetic analyses of tone. Occasionally, level tones with higher fundamental frequency values, or contour tones, have also been observed to have higher RMS amplitude values (e.g. Zee, 1978), though this has been measured less often. Given these various observations, it is hypothesised that:

1. Lopit has three contrastive lexical tones: High, Low, and Falling. The Low and High tones are characterised by low or high fundamental frequency values relative to one another, and the Falling tone is distinguished from both by a change from high to low fundamental frequency values. The Falling tone also exhibits higher duration values than the High and Low tones, and the High and Falling tones exhibit higher RMS amplitude values.

Lopit tones may also be realised differently in different tonal contexts. It was speculated in 3.5 that the additional Mid tone proposed for Lopit by Vossen (1982) may in fact be a variant realisation of the High (or Low) tone, and remarks by Turner (2001) suggest the possibility that Lopit High tones were at times perceived to be noticeably higher in pitch, perhaps when they occur as the first High tone in an utterance. If there are secondary durational and amplitude correlates to tone category in addition to fundamental frequency, it would not be unexpected for these to also vary in different contexts, particularly if these adjustments afford particular tones greater prominence than others in some contexts. Given these possibilities, it is hypothesised that:

2. In Lopit, the fundamental frequency, duration and amplitude characteristics of lexically contrastive tones have different realisations depending on where they occur in the word, and which tones occur in adjacent syllables.

6.4 Methodology

6.4.1 Participants

The participants for this production study were three adult male speakers of Lopit (AL, DA and VH), from two villages in the Dorik dialect area of the Lopit mountains and members of the Melbourne Lopit community introduced in 1.6.1. These three speakers also participated in the vowel study in Chapter 4 and the glide study in Chapter 5.

6.4.2 Materials

Given that Lopit words may have different tonal patterns for various grammatical reasons, and that investigation of these is still very much ongoing, developing a set of materials to test the phonetic realisation of Lopit tone poses a particular challenge. As discussed in 3.5.2, the role of tone in Lopit nominal morphology is more limited than in the verbal morphology, and has therefore been more accessible, and is easier to reliably elicit or control for. As such, nouns are preferred for this first experiment on tone on Lopit.

In the course of the wider project, phonetically transcribed lexical items have been added to the lexical database constructed as discussed in 1.6.2, based on various types of data collection and testing. However, given the various grammatical and other factors that may affect the tones that items have been transcribed with, particularly in the early stages of the project, a large subset of words from the lexical database were extensively checked with a Lopit speaker before stimuli for the present experiment were selected. This was done using Toney (Bird & Lee, 2014), a software tool which allows the user to play audio clips corresponding to individual words displayed in a 'cloud' on the screen, and then drag the words into different clusters that 'sound the same' according to a feature of interest. A large number of nouns recorded in the course of lexical data collection were presented in such a way (see Figure 6.1) and the Lopit speaker was asked to decide how to group them according to the tune of the word. Following these categorisations using Toney, which prompted some corrections to original transcriptions, a set of experimental materials was compiled including disyllabic nouns with all possible tonal combinations: H.H, H.L, L.H, L.L, L.F and F.L. As noted in 3.5, the Falling tone has the most restricted distribution, and though in longer nouns and in verbs it can be found adjacent to other Falling tones and, occasionally, High tones, there are so far no examples of this among disyllabic nouns. The 79 words used in the final analyses are shown Table C.5 in Appendix C.

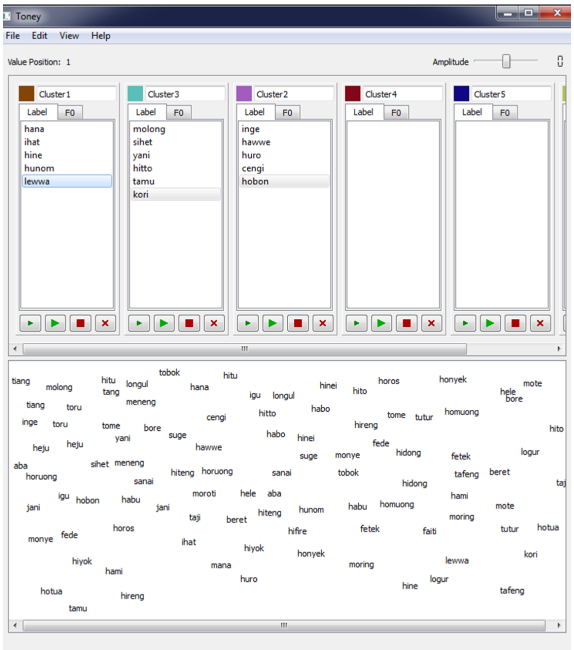


Figure 6.1: *Example of user interface for Toney software, which was used with a participant to check tone transcriptions by playing examples of Lopit words and grouping them according to shared patterns.*

Some examples from the wordlist are also shown in Table 6.1. As can be seen, there is variation in the segmental content of the words; while the wordlist materials attempt to minimise various phonetic effects to the extent possible, the amount of lexical data currently available for the language is a limiting factor. Onsets with voiced consonants, ideally sonorants, were preferenced, as well as non-close vowels in syllable nuclei, but various possible segmental combinations are represented. Similarly, for the final syllables of these disyllabic words, open syllables were preferred, but some obstruent and sonorant codas are also present.

While segmental variation is less than ideal in an investigation of tone (Xu, 2006), it is not possible to adequately control for all segmental factors at this relatively early stage in the linguistic description of the Lopit language, so these factors are instead taken into account in the statistical analyses which follow. If measures of fundamental frequency, intensity and duration are substantially affected by tone category over other factors, this should be observable, though more subtle correlations are unlikely to be revealed with the present data. As the description of Lopit progresses, it is likely that experimental materials based on verbs rather than nouns will offer more controlled datasets, given that it is very common for verb tone to change for grammatical reasons while segmental material remains the same. However, this is dependent on first understanding the contexts and functions of tone changes in Lopit verbal grammar, in order to predict and control for (or elicit) their occurrence, something which cannot yet be done confidently.

Table 6.1: *Examples of wordlist items with High, Low and Falling tones in different combinations in disyllabic words. (The full list can be found in Appendix C.)*

L.L		H.H	
rɛ̀wà	husbands PL	lɔ́rɛ́	flat rock for drying SG
màrìŋ	fence SG	máná	farm SG
L.H		**H.L**	
lɔ̀rɛ́	yam sp. SG	lɔ́mɛ̀ʔ	millet PL
bɛ̀lá	whistle SG	máŋì	mango SG
L.F		**F.L**	
lɔ̀mɛî	distance SG	bɔ̂rɛ̀	stable SG
mɔ̀ŋâ	magic stones PL	mârìʔ	ribs PL

The analyses presented here are based on the wordlist items produced in isolation. As discussed in 3.5.2 in the discussion of tone and case-marking, citation-form nouns are produced in their grammatically unmarked absolutive forms, which differ in tone pattern from the corresponding nominative forms. Two frames were also selected to elicit absolutive-marked and nominative-marked nouns in a sentence-medial context, but the resulting tokens have not been used for the analyses presented here. The nominative frame data have informed discussion elsewhere of the different tonal patterns used to indicate nominative case (e.g. Moodie & Billington, 2015), and while the absolutive frame data were intended to be used for the present study along with the citation data, some variation in speaker production for the absolutive frame data meant that the forms produced in isolation were preferred. Though speakers were consistent in the lexical tones they used for nouns in the absolutive frame, the nouns in the absolutive frame were sometimes produced (by one speaker in particular) with a word-final rise which had previously been noted to often co-occur with nominative-marked nouns, but which, as speculated in 3.5.2, is likely more closely related to focus marking. It may be that in elicited data such as this, where the frame remains the same and only the target noun changes, absolutive nouns are more likely to attract this rise. While the use of words produced in isolation introduces phrase-level effects, particularly to the right edge of each word, at this stage it is preferable to use the dataset in which speaker behaviour is most consistent. In addition, phrase-final position is in fact a very common context in which absolutive nouns occur, given that the basic constituent order in Lopit is VSO and, in a simple clause, the only elements which can follow O are members of a very small class of adverbs.

6.4.3 Elicitation and recording procedures

Spoken English prompts were produced to elicit the corresponding Lopit target utterances from the three participants, and these prompts were simultaneously presented in slideshow format on a notebook computer, with the corresponding Lopit utterance written in the working orthography currently used for the wider project. This orthography is broadly similar to that used in Ladu, Nartisio, Bong, Odingo and Gilbert (2014a) and at this stage does not indicate ATR vowel quality or tone. The aim was not to elicit read speech, but to have the written form available as a reference point if required, for example if the target word did not immediately come to mind. Each target utterance was elicited at least three times, and each token was presented on a separate slide, numbered 1, 2 or 3, instead of on one slide with an accompanying instruction to repeat three times. Participants waited for the slides to be manually advanced before producing the second and third repetitions, which, in the data collection for Chapter 4 and Chapter 5, proved to be a practical way to minimise pitch declination across repetitions and breathlessness caused by speakers attempting to produce all tokens in quick succession. Participants were asked to repeat an utterance if needed due to e.g. coughing, and sometimes produced extra repetitions, which were also included. Data were recorded in a quiet room at a sampling rate of 44.1kHz and 16-bit depth, using a Zoom H4N audio recorder, MixPre-D pre-amp, and AudioTechnica AT892c headset microphone.

6.4.4 Data processing and analysis

6.4.4.1 Segmentation and labelling

Data were segmented and labelled in Praat (Boersma & Weenink, 2016), with reference to wideband spectrograms and corresponding waveforms. Labelling in the segmental tier was broad phonetic using X-SAMPA (Wells, 1995), as in 4.4.4.1 and 5.4.4.1, and syllable nuclei were labelled followed general conventions for the identification of vowels (e.g. Keating et al., 1994; Croot & Taylor, 1995; Turk et al., 2006), as also discussed in 4.4.4.1. In addition to a segmental tier, there was a tier for the tonal category of each syllable, labelled according to impressionistic transcriptions made in the course of phonological analyses (discussed in Chapter 3) and further checked as noted above in 6.4.2. There was also a tier for the structure (onset, rhyme, coda) of each syllable, and in further coding of the data the onsets were specified as either sonorant onset or voiced/voiceless obstruent onset (or no onset, in a small number of cases), and codas, where present, as either sonorant codas (all nasals) or obstruent codas (all voiceless). The majority of word-final syllables were, however, open syllables. The word and repetition were also labelled on a separate tier. A small number of tokens were excluded due to e.g. coughing or creakiness. The final number of tokens used for these analyses was 1,362. However, the limitations of available lexical data combined with differences in the distributional patterns of tones means that the number of tokens was not balanced for each tone category; there were 664 tokens of Low tones, 441 tokens of High tones, and 257 tokens of Falling tones (and more of them in final than initial syllables).

6.4.4.2 Acoustic measures

After labelling, the data were imported to the Emu Speech Database System (Cassidy & Harrington, 2001) to create a hierarchically linked database and extract acoustic data,

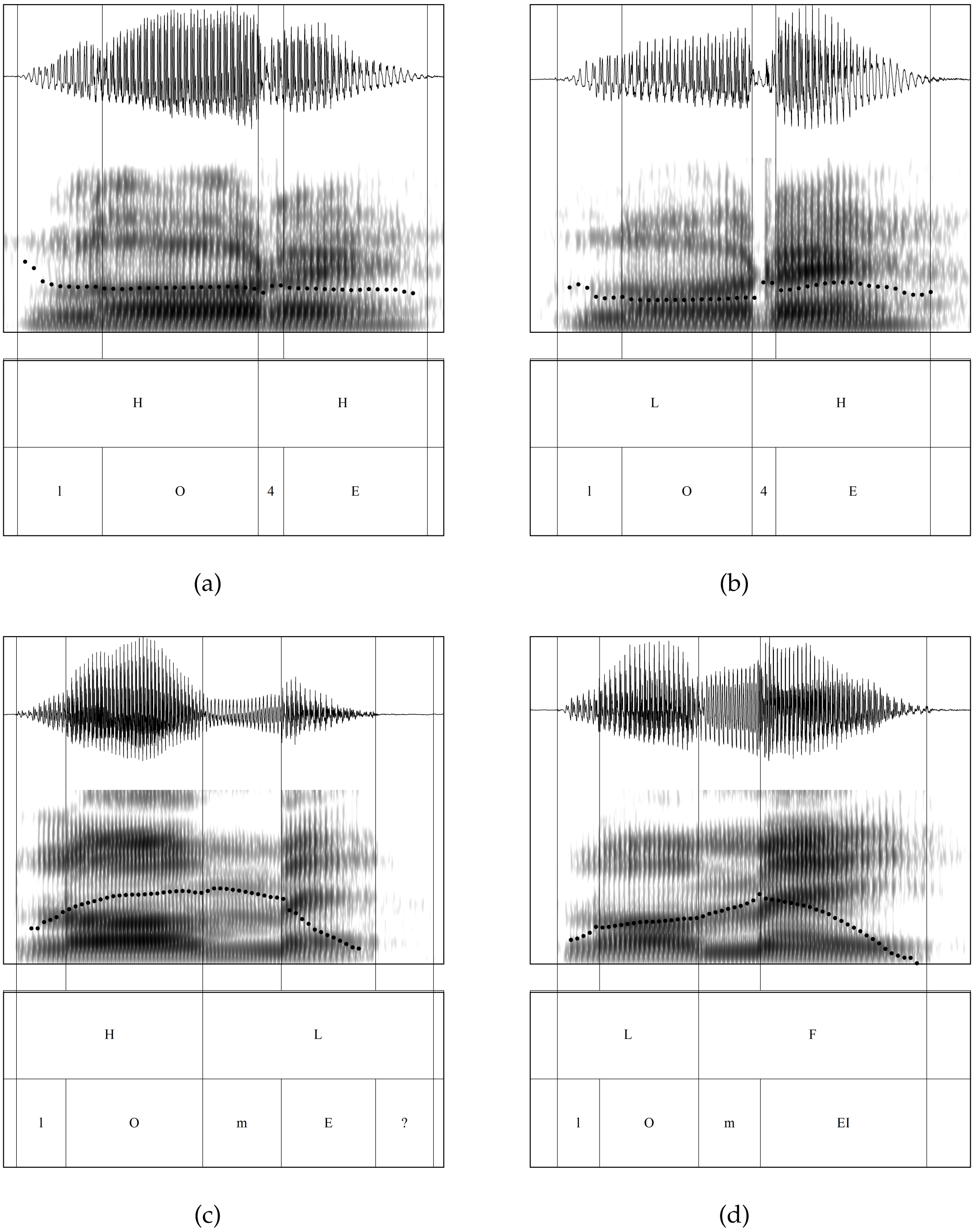


Figure 6.2: *Acoustic waveforms and spectrograms, with f0 track (range 75–300Hz), showing example tokens and labelling (first two tiers) of (a) /lɔ́rɛ́/ 'flat rock for drying* SG*' and (b) /lɔ̀rɛ́/ 'yam sp.* SG*' from VH (duration 500ms, dynamic range 50dB), and (c) /lɔ́mɛ̀ʔ/ 'millet* PL*' and (d) /lɔ̀mɛî/ 'distance* SG*' from DA (duration 700ms, dynamic range 50dB).*

and data were then queried and plotted in R (R Development Core Team, 2016) using the `emu/R` package (Harrington et al., 2012). To investigate the two hypotheses relating to the evidence for tonal contrasts as well as contextual variation in tonal realisation, the measures of interest for this experiment are fundamental frequency (f0, in Hz, extracted using the ESPS method via the Pitch and Formant Tool in Emu), intensity, as indicated by root mean square (RMS) amplitude (dB, extracted via the Speech Signal Analysis tool in Emu) and duration (ms, extracted in R based on the boundaries of labelled segments). These were extracted for the sonorant portion of the syllable rhyme, given assumptions of the syllable as the tone-bearing unit in Lopit (as noted in 3.5). For the small number of tokens with sonorant codas, there was often a 'spike' for a single point in the f0 track at the transition from vowel to sonorant; these were hand-corrected in Emu. For f0 and RMS amplitude, measures at 25%, 50% and 75% intervals in the segments of interest were extracted in R; preliminary inspection of the data suggested these as useful points for comparison, and they are often used in research on tone languages of Southeast Asia (e.g. Xu, 1997) (typically also with 0% and 100%, which are not considered here due to the likely varying effects of different onsets and codas). These results were compiled as dataframes which included, in addition to tone category (by different tonal contexts), variables of speaker, word, repetition number, onset consonant, vowel, onset type (sonorant, voiced obstruent, voiceless obstruent, none), coda consonant, and syllable structure: V, CV, CVN (nasal coda) or CVC (voiceless obstruent coda). Reported measures of duration correspond to vowel duration in the syllables of interest; for final syllables, for which there was some variation in the presence and type of coda, duration measures were based on a subset of the data containing only CV syllables. For f0, in addition to the use of values in Hz for plots and statistical tests, results for individual speakers are also reported in semitones, calculated as 12 times log base 2 of each speaker's mean f0 at the point of interest, e.g. the 25% point in a High tone, divided by their mean f0 at a reference or comparison point, such as the 25% point in a Low tone.

6.4.4.3 Statistical tests

The data were tested with Linear Mixed-Effects Models (LMEM) using the `lme4` package in R (Bates et al., 2012), following comparisons between different models to see which factors improved model performance, and accompanied by visual checks of variance (homoscedacity) and the normality of the distribution using plots of residuals and fitted values. In this experiment, the main effect of tone category (where the categorisation also includes the identity of the preceding or following tone) is investigated. For all tests of f0 values, speaker and word were included as random effects. For tests of f0 values at the 75% point in final syllables, the models were slightly improved with syllable type as an additional random factor, and for f0 in final High tones (preceded by either Low or High tones), the additional random effect of vowel also slightly improved the model. For both duration and intensity, speaker and word were also included as random effects in all comparisons. For intensity comparisons at 75% in final syllables, the inclusion of syllable type as an additional random effect improved the model, and as noted in 6.4.4.2, for duration comparisons in final syllables, a subset of the data containing CV syllables only was used.

The validity of each analysis in this experiment was first checked using a likelihood ratio test, to compare a model including both the fixed and random effects with a model including only the random effects and thereby corresponding to the null hypothesis. As noted in previous chapters, the absence of a significant difference between these models indicates that the fixed effect does not have a more substantial influence on the measure of interest than the random effects, and that the relevant hypothesis must be rejected. Where there was a significant difference between the models, the significance of any differences between between tone categories was inspected using Tukey's Honest Significant Difference post-hoc tests. Throughout this chapter, results are reported as Pearson's Chi-Square values (χ^2) and associated p-values, with p-values up to 0.05 accepted as significant. The results of the post-hoc tests are summarised in tables throughout, and descriptive statistics (number of tokens, mean, standard deviation, median, minima, maxima) for f0, intensity and duration measurements are contained in Appendix D (Table D.18 to Table D.23).

6.5 Results

6.5.1 Fundamental frequency

6.5.1.1 f0 comparisons for H, L and F tones preceding and following L tones

Figure 6.3 shows f0 trajectories for High, Low and Falling tones in syllable rhymes preceding and following a Low toned syllable in disyllabic words. Trajectories are plotted for each individual speaker; given the small number of speakers this is preferable to averaging across all three. As can be seen, there are clear differences between the f0 trajectories for the three tone categories in initial syllables. The High and Falling tones begin with high average f0 values compared to the Low tone, and the trajectories for the High and Low tones are quite level, whereas the contour for the Falling tone diverges from that of the High early in the rhyme, and falls to around the level of the Low tone, or lower. It can also be seen that the three participants have different pitch ranges; based on the minimum and maximum f0 values for each speaker in the dataset (from the three measurement points), the narrowest pitch range is for VH (11 semitones), followed by AL (12 semitones), compared to DA (16 semitones).

Results for f0 at 25%, 50% and 75% into the sonorant portion of the rhyme are summarised in Table 6.2. The likelihood ratio test for data at 25% into the rhyme in initial syllables is significant (χ^2(2, N=277)= 37.31, p<0.001), and post-hoc tests reveal that f0 values for the Low tone are significantly lower than for the High tone by an estimated 18 $\pm$ 2 Hz, and lower than for the Falling tone by 15 $\pm$ 3 Hz. The High and Falling tones do not significantly differ from one another at this point (p=0.77). At 50%, the likelihood ratio test is also significant (χ^2(2, N=277)= 38.04, p<0.001), and f0 values for the Low tone remain significantly lower than for the High, by 19 $\pm$ 2 Hz, and are lower than for the Falling by 8 $\pm$ 3 Hz. The difference between the High and Falling, as f0 falls for the Falling tone, is also significant, with f0 for the Falling tone being 11 $\pm$ 3 Hz lower than for the High at this point. At 75%, the likelihood ratio test is again significant (χ^2(2, N=277)= 37.94, p<0.001); differences between the Low and the Falling tones are no longer significant, as the f0 trajectory for the Falling tone now approaches its lowest values (p=0.87),

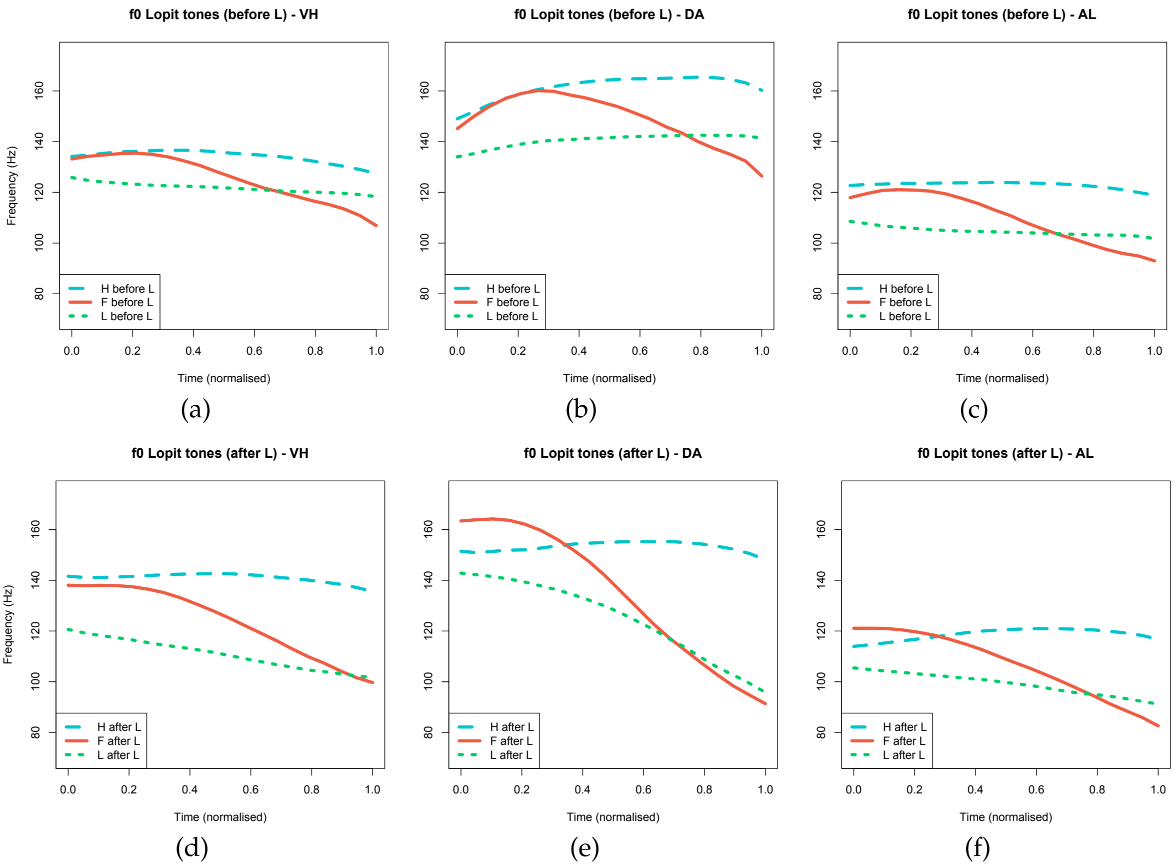


Figure 6.3: *Time-normalised f0 trajectories (Hz) for High, Low and Falling tones preceding and following Low tones in disyllabic words (for the sonorant portion of the syllable rhyme), for each participant*

but values for the High tone are significantly higher than for the Falling by 20 $\pm$ 3 Hz, and higher than for the Low tone by 18 $\pm$ 3 Hz.

In final syllables, the patterns are broadly similar, as can be seen in Figure 6.3. The Falling tone again begins with quite high f0 values, especially for DA, but still begins to fall similarly early in the rhyme. In this context, f0 trajectories for both the Falling and Low tones fall quite low, which is not unsurprising utterance-finally, but f0 values for the High tone remain relatively level. Significant differences are found for the same comparisons as in initial syllables; that is, there is no difference between High and Falling tones at 25%, and no difference between Falling and Low tones at 75%, but significant differences between pairs of tones at all other points (Table 6.2). Specifically, the findings are that the likelihood ratio test for data at 25% into the rhyme in initial syllables is significant (χ^2(2, N=448)= 63.34, $p<0.001$), and post-hoc tests confirm that at 25%, f0 values for the Low tone are significantly lower than for the High by 17 $\pm$ 2 Hz, and lower than for the Falling by 19 $\pm$ 2 Hz. As in initial syllables, the High and Falling tones do not differ significantly at 25% (p=0.71). The likelihood ratio test is also significant at 50% (χ^2(2, N=448)= 68.75, $p<0.001$); f0 for the Low tone is significantly lower than for the High by 26 $\pm$ 2 Hz mid-way into the rhyme, and lower than for the Falling by 11 $\pm$ 2 Hz. At this point, f0 for the Falling tone is also 15 $\pm$ 2 Hz lower than for the High tone. The likelihood ratio test for data at 75% is again significant (χ^2(2, N=448)= 94.32, $p<0.001$); the Low and Falling tones no longer differ significantly in f0 (p=0.54), but the High tone has f0 values 34 $\pm$ 2 Hz higher than for the Low tone, and 32 $\pm$ 2 Hz higher than for the Falling tone.

Based on the mean f0 values for each speaker at the three measurement points, the difference between High and Low tones preceding Low tones is 3 semitones for AL, 2–3 semitones for DA, and 2 semitones for VH, and in final syllables the differences in 2–4 semitones for AL, 2–5 for DA, and 3–5 for VH. Falling tones differ from Low tones by 2 semitones for each speaker early in the syllable rhyme, and compared to High tones, late in the rhyme, they differ by 3 semitones for AL and DA and 2 semitones for VH.

Table 6.2: *Results of statistical comparisons between High, Falling and Low tones (preceding and following Low tones) for f0 values at selected measurement points (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

f0 comparison	at	result
High before Low ∼ Falling before Low	25%	-
	50%	**
	75%	***
Falling before Low ∼ Low before Low	25%	***
	50%	*
	75%	-
Low before Low ∼ High before Low	25%	***
	50%	***
	75%	***
High after Low ∼ Falling after Low	25%	-
	50%	***
	75%	***
Falling after Low ∼ Low after Low	25%	***
	50%	***
	75%	-
Low after Low ∼ High after Low	25%	***
	50%	***
	75%	***

6.5.1.2 f0 comparisons for L tones preceding and following H, F and L tones

F0 characteristics for tones occurring in different tonal environments were also investigated. Specifically, realisations of the Low and High tones preceding and following different tones were explored. Given that the Falling tone only occurs adjacent to Low tones in the disyllabic nouns in this dataset, its realisations in different tonal environments cannot be explored here. Figure 6.4 shows f0 trajectories for Low tones preceding and following High, Falling, and Low tones. For initial syllables, the plots show no obvious pattern; there are only minimal differences between the different Low tone trajectories for AL (c), and slightly different tendencies for DA and VH, for example the Low tone preceding High being slightly lower than a Low tone preceding a Low for DA (b), but for VH, Low before High being slightly *higher* than Low before Low (a). Likelihood ratio tests indicate that there is no significant difference between the models with and without tone context as a fixed effect at 25% (χ^2(2, N=352)= 3.62, p=0.16), at 50% (χ^2(2, N=352)= 2.85, p=0.24) or at 75% (χ^2(2, N=352)= 0.74, p=0.69) in initial syllables, meaning that the influence of tone context is not greater than that of the random effects on initial Low tones, and the null hypothesis cannot be rejected. The mean f0 differences between initial Low tones followed by either High, Low or Falling tones are equivalent to less than 1 semitone for each speaker.

Among Low tones following High, Falling and Low tones, as also shown in Figure 6.4, there are some significant differences, as summarised in Table 6.3. A likelihood ratio test for f0 values at 25% has a significant result ($\chi^2(2, N{=}312){=}\ 22.76, p{<}0.01$); post-hoc tests indicate that at this point, a Low tone following a Low is 9 $\pm$ 2 Hz higher than a Low tone following a High, and 13 $\pm$ 3 Hz higher than a Low tone following a Falling tone. There are no significant differences between Low tones following High and Falling tones (p=0.34). A likelihood ratio test at 50% is again significant ($\chi^2(2, N{=}312){=}\ 25.57$, $p{<}0.01$); though there are still no significant differences between Low tones following High and Falling tones (p=0.87), Low tones following a Low remain higher than a Low tone following a High by 10 $\pm$ 2 Hz, and higher than a Low tone following a Falling by 11 $\pm$ 3 Hz. At 75%, a likelihood ratio test is again significant ($\chi^2(2, N{=}312){=}\ 11.18, p{<}0.01$); Low tones following a Low are 8 $\pm$ 3 Hz higher than Low tones following a High, and also 8 $\pm$ 3 Hz higher than Low tones following a Falling tone, but there are again no significant differences for Low tones following High compared to Falling (p=1.00). Based on mean f0 values for each speaker, the Low tones following High differ from Low tones following Low by 1 semitone for AL, 2 semitones for DA, and 1 semitone for VH, and Low tones following Falling differ from Low tones following Low by 2 semitones for AL, 2–3 semitones for DA, and less than 1 semitone for VH.

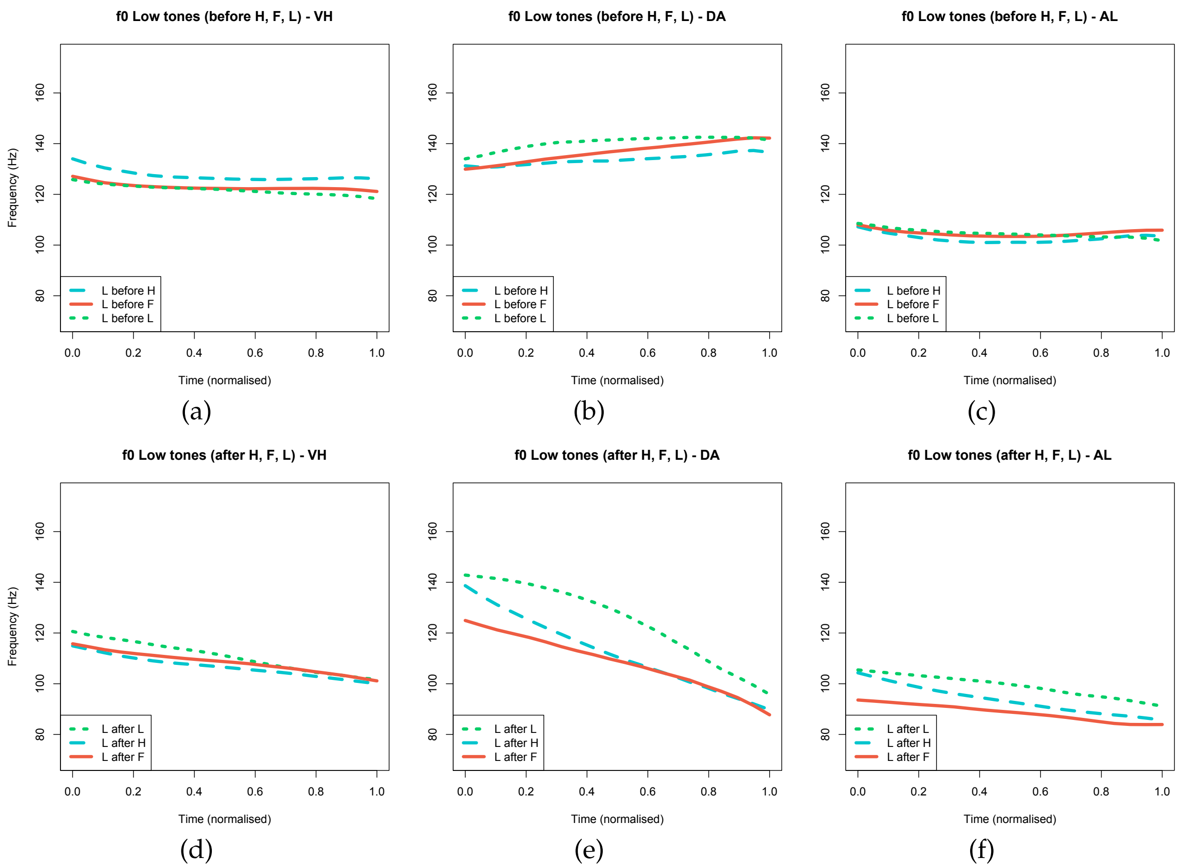


Figure 6.4: *Time-normalised f0 trajectories (Hz) for Low tones preceding and following High, Low and Falling tones in disyllabic words (for the sonorant portion of the syllable rhyme), for each participant.*

Table 6.3: *Results of statistical comparisons between Low tones (preceding and following High, Falling and Low tones) for f0 values at selected measurement points (***=p<0.001, **=p<0.01, *=p<0.05, - = NS, ∅ = likelihood ratio test not significant).*

f0 comparison	at	result
Low before High ∼ Low before Falling	25%	∅
	50%	∅
	75%	∅
Low before Falling ∼ Low before Low	25%	∅
	50%	∅
	75%	∅
Low before Low ∼ Low before High	25%	∅
	50%	∅
	75%	∅
Low after High ∼ Low after Falling	25%	-
	50%	-
	75%	-
Low after Falling ∼ Low after Low	25%	***
	50%	***
	75%	*
Low after Low ∼ Low after High	25%	***
	50%	***
	75%	**

6.5.1.3 f0 comparisons for H tones preceding and following H and L tones

In Figure 6.5, average f0 trajectories are shown for High tones preceding and following Low tones and other High tones. A pattern is apparent in the plots for initial syllables, with the trajectory for the High tones before Low tones having higher f0 values than for High tones preceding High tones. Likelihood ratio tests reveal that this difference is significant at the three measurement points; at 25% (χ^2(1, N=230)= 8.34, $p<0.01$), High tones preceding Low tones are 9 ± 3 Hz higher than High tones preceding High, and at 50% (χ^2(1, N=230)= 8.10, $p<0.01$) they are a similar 9 ± 3 Hz higher, and at 75% (χ^2(1, N=230)= 5.46, $p<0.05$) they are 7 ± 3 Hz higher than High tones preceding High. The mean f0 differences for each speaker between High tones preceding High compared to Low tones are equivalent to 1 semitone.

For High tones following Low and High tones, also shown in Figure 6.5, there is also a tendency for the average f0 trajectories for High tones following Low to be slightly higher than for High tones following High. A likelihood ratio test at 25% is not significant (χ^2(1, N=211)= 1.18, p=0.28), but a test at 50% is (χ^2(1, N=211)= 5.06, $p<0.05$), showing that High tones after Low tones are 6 ± 3 Hz higher than High tones after other High tones. A test at 75% is also significant (χ^2(1, N=211)= 6.40, $p<0.05$); at this point, High tones after Low tones are 8 ± 3 Hz higher than High tones after High tones. These results are summarised in Table 6.4. The mean f0 differences for each speaker between High tones following High compared to Low tones are equivalent to les than 1 semitone for AL and DA, and 1–2 semitones for VH.

Table 6.4: *Results of statistical comparisons between High tones (preceding and following High and Low tones) for f0 values at selected measurement points (***=p<0.001, **=p<0.01, *=p<0.05, - = NS, ∅ = likelihood ratio test not significant).*

f0 comparison	at	result
High before High ∼ High before Low	25%	**
	50%	**
	75%	*
High after High ∼ High after Low	25%	∅
	50%	*
	75%	**

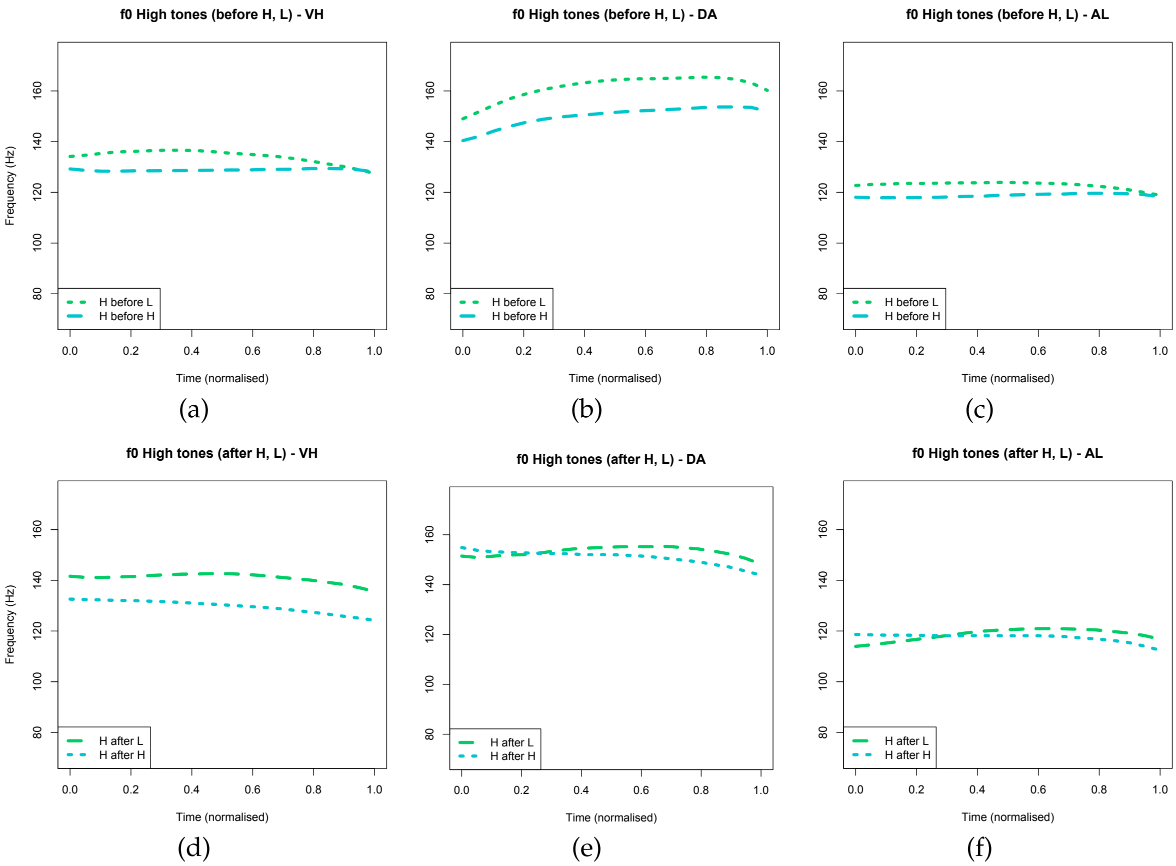


Figure 6.5: *Time-normalised f0 trajectories (Hz) for High tones preceding and following High and Low tones in disyllabic words (for the sonorant portion of the syllable rhyme), for each participant.*

6.5.1.4 f0 comparisons for H and L tones preceding and following H and L tones

Given that the preceding sections show that the f0 characteristics of High and Low tones respectively may differ in different tonal contexts, and that they may be most distinct when adjacent to syllables with a different tonal specification, it is worth checking whether the observed differences between High and Low tones also hold in words with H.H and L.L patterns. In Figure 6.6, average f0 trajectories are shown for initial and final High and Low tones adjecent to syllables which also bear High and Low tones. The plotted trajectories indicate that High tones in initial syllables do have higher f0 values than Low tones in H.H compared to L.L words. A likelihood ratio test confirms that this observable difference is significant at the three measurement points; at 25% (χ^2(1, N=261)= 13.40, $p<0.01$), High tones preceding High tones are 9 $\pm$ 2 Hz higher than Low tones preceding Low, and at 50% (χ^2(1, N=261)= 16.93, $p<0.01$) they are 11 $\pm$ 2 Hz higher, and at 75% (χ^2(1, N=261)= 20.25, $p<0.01$) they are 12 $\pm$ 2 Hz higher than Low tones preceding Low. The mean f0 differences between High and Low tones when they precede tones of the same category are equivalent to 2–3 semitones for AL, and 1 semitone for DA and VH.

For High tones following High tones, compared to Low tones following Low tones, similar patterns are apparent in the average f0 trajectories shown in Figure 6.6. Likelihood ratio tests confirm that the f0 differences are significant; at 25% (χ^2(1, N=292)= 33.07, $p<0.01$), High tones preceding High tones are 16 $\pm$ 2 Hz higher than Low tones preceding Low, and at 50% (χ^2(1, N=292)= 43.61, $p<0.01$) they are 21 $\pm$ 2 Hz higher, and at 75% (χ^2(1, N=292)= 53.83, $p<0.01$) they are 27 $\pm$ 2 Hz higher than Low tones preceding Low. The mean f0 differences between High and Low tones when they precede tones of the same category are equivalent to 2–4 semitones for AL, 2–5 semitones for DA and 2–3 semitones for VH.

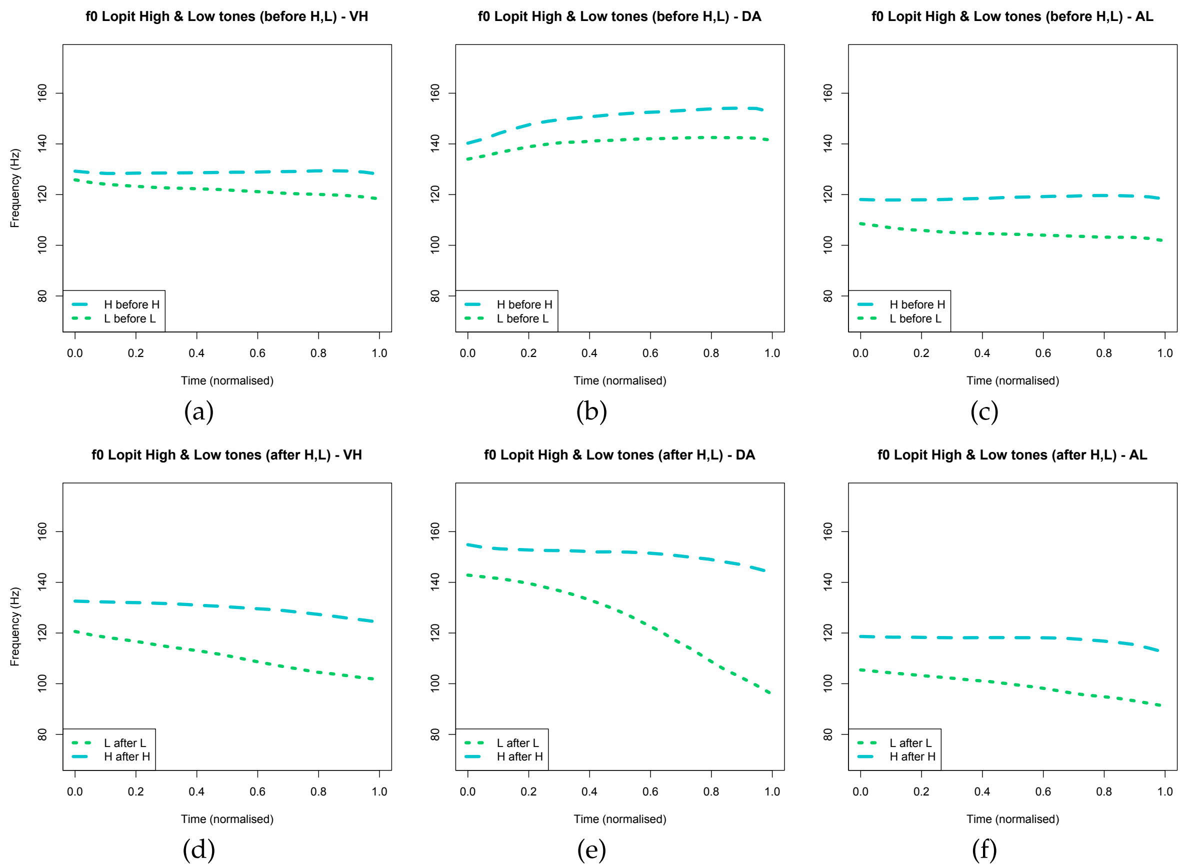


Figure 6.6: *Time-normalised f0 trajectories (Hz) for High and Low tones preceding and following other High and Low tones in disyllabic words (for the sonorant portion of the syllable rhyme), for each participant.*

Table 6.5: *Results of statistical comparisons between High and Low tones (preceding and following High and Low tones) for f0 values at selected measurement points (***=p<0.001, **=p<0.01, *=p<0.05, - = NS, ∅ = likelihood ratio test not significant).*

f0 comparison	at	result
High before High ∼ Low before Low	25%	***
	50%	***
	75%	***
High after High ∼ Low after Low	25%	***
	50%	***
	75%	***

6.5.2 Intensity

6.5.2.1 Intensity comparisons for H, L and F tones preceding and following L tones

Intensity trajectories for High, Falling and Low tones preceding and following Low tones are presented in Figure 6.7. While some minor differences can be observed in the averaged trajectories for initial syllables, which is not surprising given there is a relationship between f0 and RMS amplitude, there are no significant results for likelihood ratio tests at 25% (χ^2(2, N=277)= 2.06, p=0.36), at 50% (χ^2(2, N=277)= 2.76, p=0.25), or at 75% (χ^2(2, N=277)= 3.19, p=0.20). This indicates that the fixed effect of tone does not have a significant influence on intensity values in initial syllables.

For final syllables, also shown in Figure 6.7, a small number of significant differences can be observed (summarised in Table 6.6). A likelihood ratio test at 25% is significant (χ^2(2, N=448)= 7.06, $p<0.05$); at this point, Low tones have intensity values an estimated 3 ± 1 dB lower than those of Falling tones. There are no significant differences Low and High tones (p=0.21) or High and Falling tones (p=0.95). At 50%, a likelihood ratio test is also significant (χ^2(2, N=448)= 10.96, $p<0.01$); Low tones again have intensity values lower than that of Falling tones, by 3 ± 1 dB, and Low tones are also an estimated 3 $\pm$ 1 dB lower than High tones in intensity. High and Falling tones show no significant differences at this point (p=1.00). A test at 75% is significant (χ^2(2, N=448)= 7.05, $p<0.05$), and post-hoc tests indicate that Low tones have, at this point, intensity values 3 ± 1 dB lower than for High tones. The difference between Low and Falling tones approaches but does not reach significance levels (p=0.08), and there is not a significant intensity difference between High and Falling tones at this point (p=0.64).

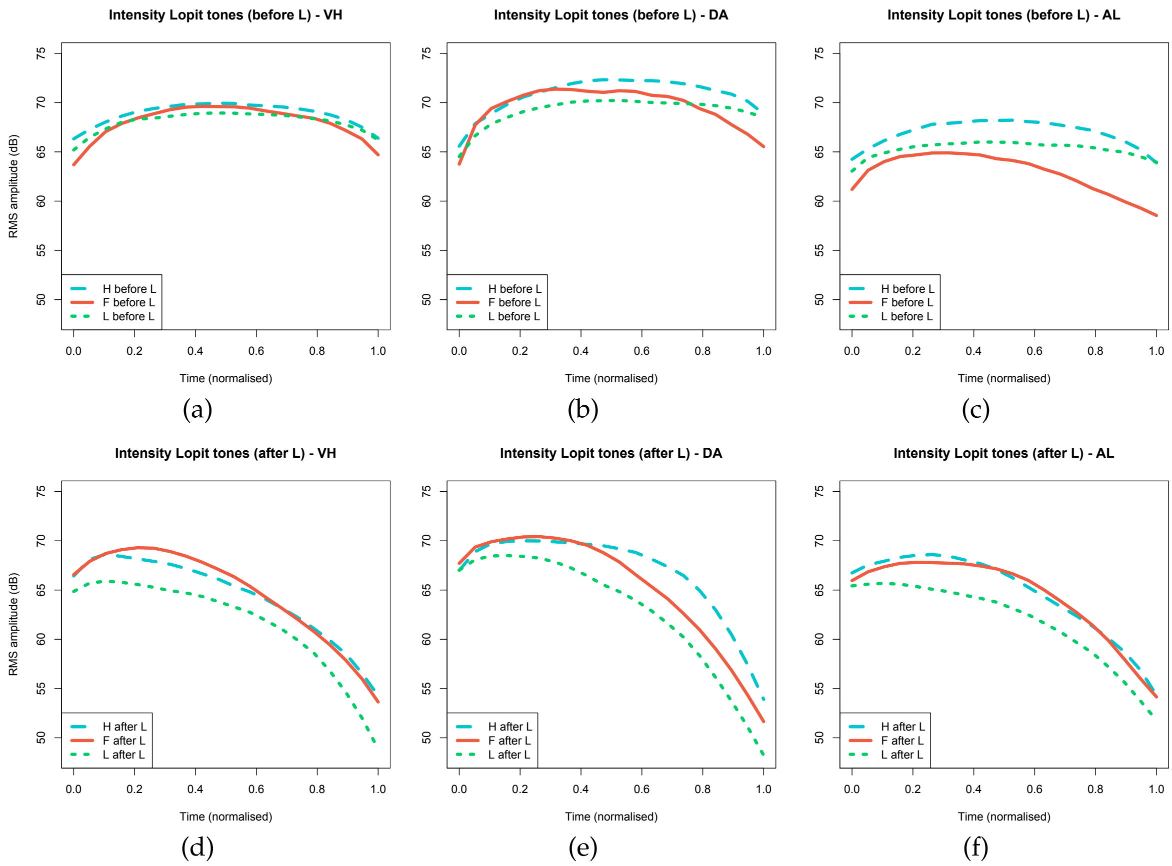


Figure 6.7: *Time-normalised intensity trajectories (dB-RMS) for High, Low and Falling tones preceding and following Low tones in disyllabic words (for the sonorant portion of the syllable rhyme), for each participant.*

Table 6.6: *Results of statistical comparisons between High, Falling and Low tones (preceding and following Low tones) for intensity values at selected measurement points (***=p<0.001, **=p<0.01, *=p<0.05, - = NS, ∅ = likelihood ratio test not significant).*

Intensity comparison	at	result
High before Low ∼ Falling before Low	25%	∅
	50%	∅
	75%	∅
Falling before Low ∼ Low before Low	25%	∅
	50%	∅
	75%	∅
Low before Low ∼ High before Low	25%	∅
	50%	∅
	75%	∅
High after Low ∼ Falling after Low	25%	-
	50%	-
	75%	-
Falling after Low ∼ Low after Low	25%	*
	50%	**
	75%	-
Low after Low ∼ High after Low	25%	-
	50%	*
	75%	*

6.5.2.2 Intensity comparisons for L tones preceding and following H, F and L tones

Figure 6.8 shows average intensity trajectories for Low tones preceding and following High, Falling and Low tones. For initial syllables, likelihood ratio tests are not significant at 25% (χ^2(2, N=352)= 1.88, p=0.39), at 50% (χ^2(2, N=352)= 2.40, p=0.30), or at 75% (χ^2(2, N=352)= 1.75, p=0.42). In final syllables, there are some differences, as shown in Table 6.7. A likelihood ratio test at 25% returns a significant result (χ^2(2, N=312)= 10.29, $p<0.01$), and post-hoc tests indicate that Low tones following Falling tones are an estimated 6 $\pm$ 2 dB lower in intensity than Low tones following Low tones at this measurement point. The estimated 3 $\pm$ 1 dB difference between Low tones following Low tones compared to Low tones following High tones falls just outside significance levels (p=0.05), and there is no difference between Low tones following High compared to Falling tones (p=0.37). At 50%, the likelihood ratio test is also significant (χ^2(2, N=312)= 8.15, $p<0.05$), and intensity values for Low tones following Falling tones are an estimated 4 $\pm$ 2 dB lower than for Low tones following other Low tones, and values for Low tones following High tones are an estimated 3 $\pm$ 1 dB lower than for Low tones following Low tones. Differences between Low tones following High compared to Falling tones are not significant (p=0.76). At 75%, the likelihood ratio test is again significant (χ^2(2, N=312)= 7.64, $p<0.05$); at this point Low tones following both Falling and High tones are an estimated 4 $\pm$ 1 dB lower in intensity values than Low tones following Low tones. As at earlier points, there are no significant differences for Low tones following High compared to Falling tones (p=1.00).

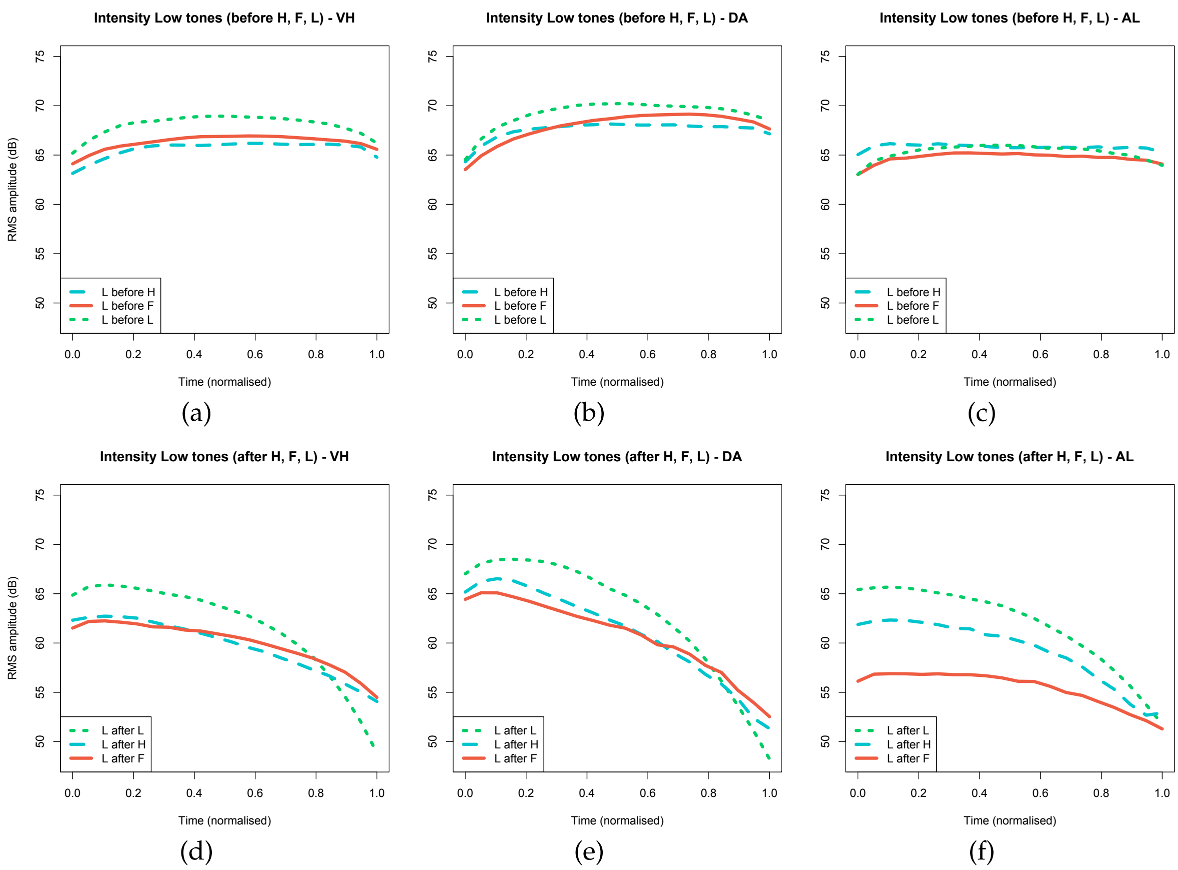


Figure 6.8: *Time-normalised intensity trajectories (dB-RMS) for Low tones preceding and following High, Low and Falling tones in disyllabic words (for the sonorant portion of the syllable rhyme), for each participant.*

Table 6.7: *Results of statistical comparisons between Low tones (preceding and following High, Falling and Low tones) for intensity values at selected measurement points (***=p<0.001, **=p<0.01, *=p<0.05, - = NS, ∅ = likelihood ratio test not significant).*

Intensity comparison	at	result
Low before High ∼ Low before Falling	25%	∅
	50%	∅
	75%	∅
Low before Falling ∼ Low before Low	25%	∅
	50%	∅
	75%	∅
Low before Low ∼ Low before High	25%	∅
	50%	∅
	75%	∅
Low after High ∼ Low after Falling	25%	-
	50%	-
	75%	-
Low after Falling ∼ Low after Low	25%	**
	50%	*
	75%	*
Low after Low ∼ Low after High	25%	-
	50%	*
	75%	**

6.5.2.3 Intensity comparisons for H tones preceding and following H and L tones

Figure 6.9 shows average intensity trajectories for High tones preceding and following High and Low tones. For initial syllables, likelihood ratio tests are not significant at 25% (χ^2(1, N=230)= 0.82, p=0.37), at 50% (χ^2(1, N=230)= 0.84, p=0.36), or at 75% (χ^2(1, N=230)= 0.26, p=0.61). Similar results are found for the intensity of High tones in final syllables; there are no significant results for the likelihood ratio tests at 25% (χ^2(1, N=211)= 0.67, p=0.41), at 50% (χ^2(1, N=211)= 0.61, p=0.43), or at 75% (χ^2(1, N=211)= 0.01, p=0.94).

Table 6.8: *Results of statistical comparisons between High tones preceding and following High and Low tones) for intensity values at selected measurement points (***=p<0.001, **=p<0.01, *=p<0.05, - = NS, ∅ = likelihood ratio test not significant).*

Intensity comparison	at	result
High before High ∼ High before Low	25%	∅
	50%	∅
	75%	∅
High after High ∼ High after Low	25%	∅
	50%	∅
	75%	∅

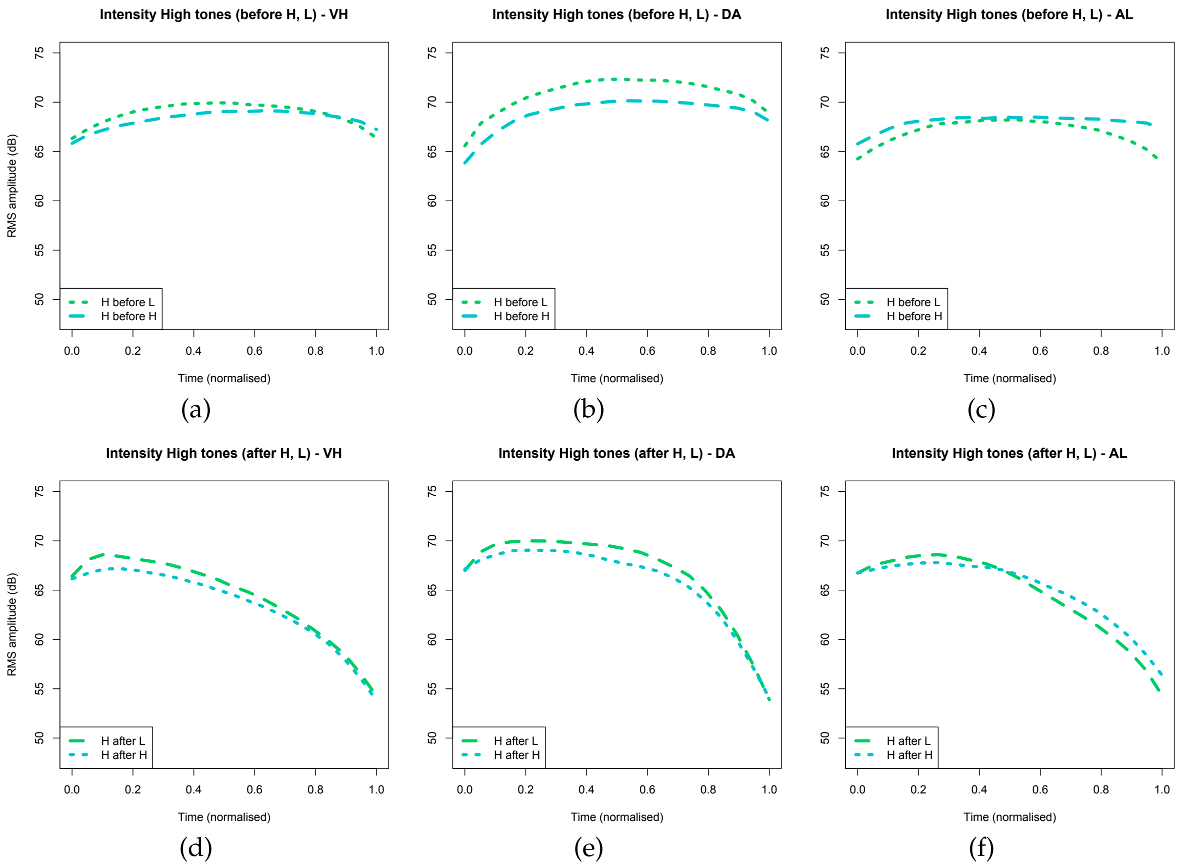


Figure 6.9: *Time-normalised intensity trajectories (dB-RMS) for High tones preceding and following High and Low tones in disyllabic words (for the sonorant portion of the syllable rhyme), for each participant.*

6.5.2.4 Intensity comparisons for H and L tones preceding and following H and L tones

Figure 6.10 shows average intensity trajectories for High and Low tones adjacent to other High and Low tones. For initial syllables, though there are some observable differences in average values for one speaker, there are no significant results for likelihood ratio tests based on values at 25% (χ^2(1, N=261)= 0.28, p=0.59), at 50% (χ^2(1, N=261)= 0.45, p=0.50), or at 75% (χ^2(1, N=261)= 0.65, p=0.42). While all three speakers show some differences in average trajectories in final syllables, a likelihood ratio test at 25% is not significant (χ^2(1, N=292)= 1.25, p=0.26), though the test for values at 50% approaches significance (χ^2(1, N=292)= 3.19, p=0.07), and reaches significance for values at 75% (χ^2(1, N=292)= 4.35, p=0.04). At this point, High tones following High tones have values an estimated 2 $\pm$ 1 dB higher than Low tones following Low tones.

Table 6.9: *Results of statistical comparisons between High and Low tones (preceding and following High and Low tones) for intensity values at selected measurement points (***=p<0.001, **=p<0.01, *=p<0.05, - = NS, ∅ = likelihood ratio test not significant).*

Intensity comparison	at	result
High before High ∼ Low before Low	25%	∅
	50%	∅
	75%	∅
High after High ∼ Low after Low	25%	∅
	50%	∅
	75%	*

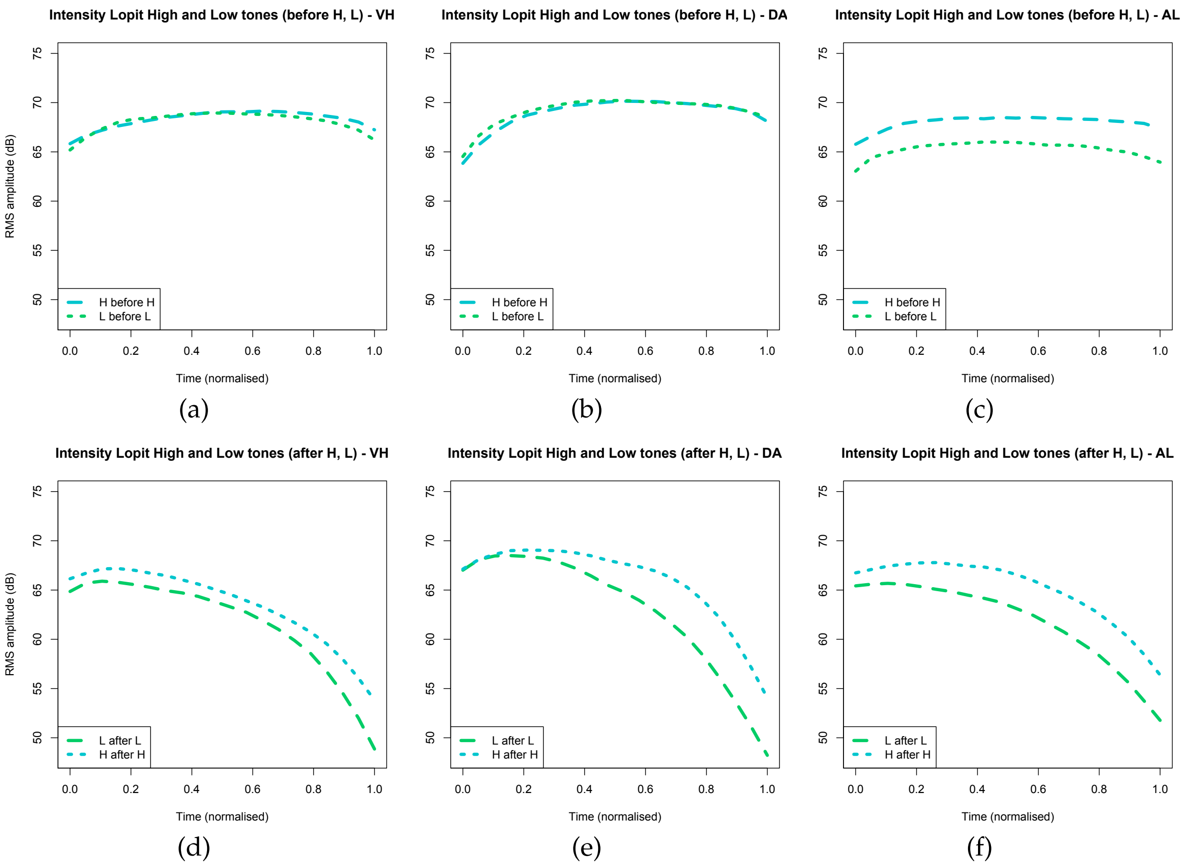


Figure 6.10: *Time-normalised intensity trajectories (dB-RMS) for High and Low tones preceding and following other High and Low tones in disyllabic words (for the sonorant portion of the syllable rhyme), for each participant.*

6.5.3 Duration

6.5.3.1 Duration comparisons of H, L and F tones preceding and following L tones

Duration values for High, Falling and Low tones preceding and following Low tones are shown in the boxplots in Figure 6.11. As noted in 6.4.4.2, reported values correspond to vowel duration, and for final syllables, a subset of the data with open syllables only was used. It can be seen that in initial syllables, duration values for the Falling tone tend towards higher values than for the High and Low tones. However, a likelihood ratio test indicates that the fixed effect of tone does not have a greater influence on duration than the random factors; the tests are not significant for data in initial syllables (χ^2(2, N=277)= 3.96, p=0.14). The small number of initial Falling tone tokens compared to High and Low tone tokens (46, from only 5 words, compared to 100 and 131 tokens, respectively) is likely a limiting factor here; if the statistical tests are performed without the inclusion of word as a random effect, the differences are significant, suggesting that more robust results may emerge if more words with initial Falling tones can be included in later work.

For vowel duration in final (CV only) syllables, some minor differences can be observed in the distribution of duration values for different tones, but a likelihood ratio test is not significant (χ^2(2, N=296)= 2.76, p=0.025). This suggests that as for the vowels in initial syllables discussed above, tone does not have a greater influence on duration than other factors. However, also as above, the small and relatively unbalanced nature of the data likely limits the possibilities for any patterns to emerge (for these CV syllables, 147 tokens are Falling tones, compared to 95 and 54 for Low and High tones respectively). If the random effect of word is removed, the result of the likelihood ratio test approaches significance (p=0.08), and the higher duration values for Falling compared to Low tones also approach significance in post-hoc tests (p=0.08). Recalling that these tokens were drawn from words produced in isolation, there may also be boundary effects on duration in final compared to initial syllables, though there is not a clear pattern across the three speakers.

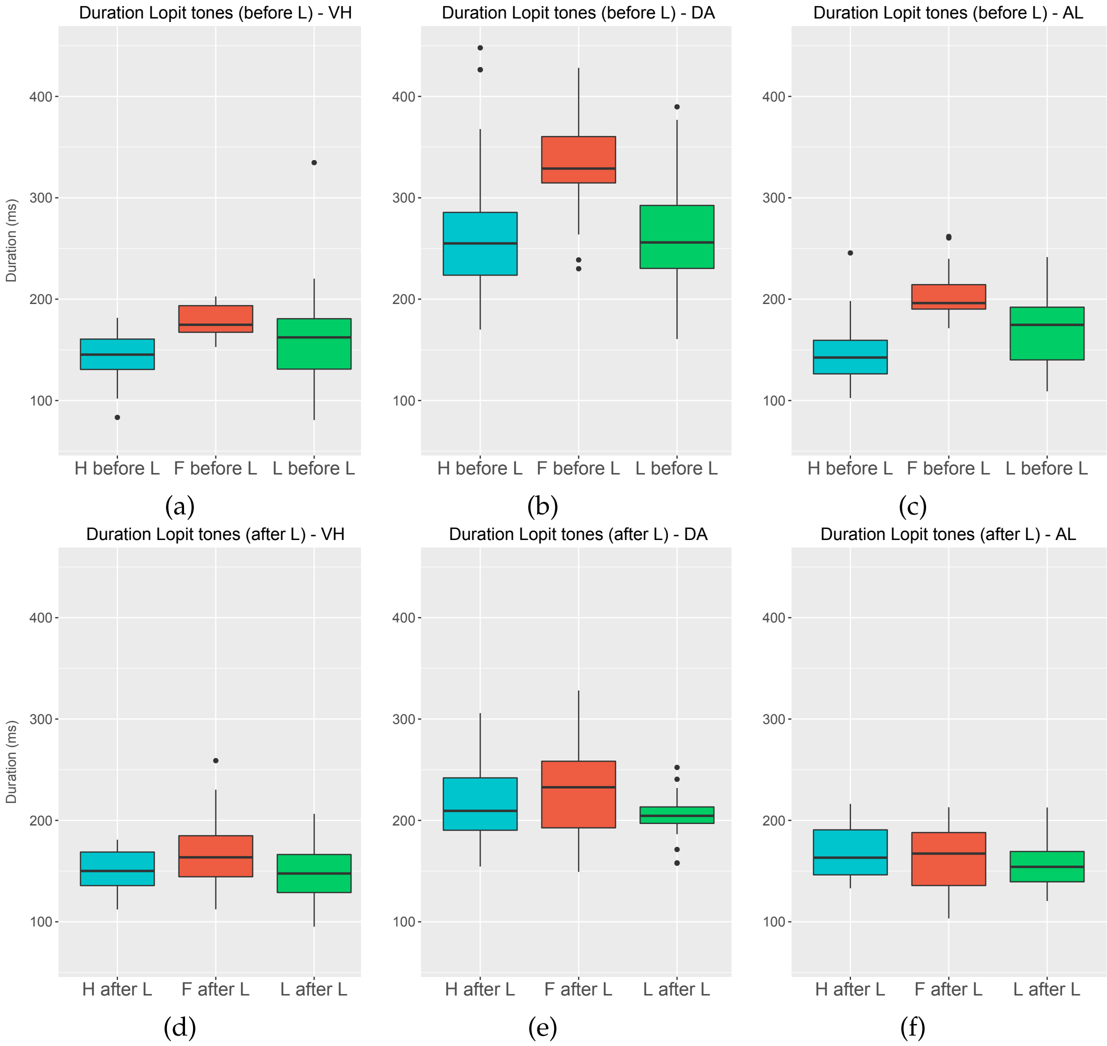


Figure 6.11: *Duration (ms) for High, Low and Falling tones preceding and following Low tones in disyllabic words (for the vocalic portion of the syllable), for each participant.*

Table 6.10: *Results of statistical comparisons between vowels with High, Falling and Low tones (preceding and following Low tones) for duration values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS, ∅ = likelihood ratio test not significant).*

Duration comparison	result
High before Low ∼ Falling before Low	∅
Falling before Low ∼ Low before Low	∅
Low before Low ∼ High before Low	∅
High after Low ∼ Falling after Low	∅
Falling after Low ∼ Low after Low	∅
Low after Low ∼ High after Low	∅

6.5.3.2 Duration comparisons of L preceding and following H, L and F tones

In Figure 6.12, duration boxplots for Low tones preceding and following High, Falling and Low tones are shown, with some interesting results. A likelihood ratio test for the data for initial syllables is significant (χ^2(2, N=352)= 19.45, p<0.001), and post-hoc tests reveal that the patterns observed in the boxplots correspond to significant differences; Low tones preceding Falling tones are shorter than Low tones preceding other Low tones by an estimated 47 ± 10 ms, and Low tones preceding Falling tones are also shorter than Low tones preceding High tones by 35 ± 12 ms. There are no significant duration differences for Low tones preceding High compared to Low tones preceding Low (p=0.61).

Duration boxplots for Low tones in final syllables (CV only) show a clear pattern of higher duration values for Low tones following Low tones. A likelihood ratio test for these data returns a significant result (χ^2(2, N=119)= 12.25, p<0.01), and post-hoc tests confirm specific differences; Low tones following Falling tones are an estimated 47 ± 16 ms shorter than Low tones following other Low tones, and Low tones following High tones are 41 ± 13 ms shorter than Low tones following Low tones. Given that restricting the comparisons of duration in final syllables to CV syllables only means that, in this case, the token numbers are even lower and more unbalanced than above (95 Low compared to 12 Falling and 12 High), it is worth noting that the same patterns are observable for Low tones in CVC syllables, as shown in Figure 6.13; duration values are overall lower in CVC syllables (139 tokens), but still highest for Low tones following Low tones (statistical results are almost identical for all syllables as for CV syllables only, but at p<0.001).

Table 6.11: *Results of statistical comparisons between vowels with Low tones (preceding and following High, Falling and Low tones) for duration values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

Duration comparison	result
Low before High ∼ Low before Falling	**
Low before Falling ∼ Low before Low	***
Low before Low ∼ Low before High	-
Low after High ∼ Low after Falling	-
Low after Falling ∼ Low after Low	**
Low after Low ∼ Low after High	**

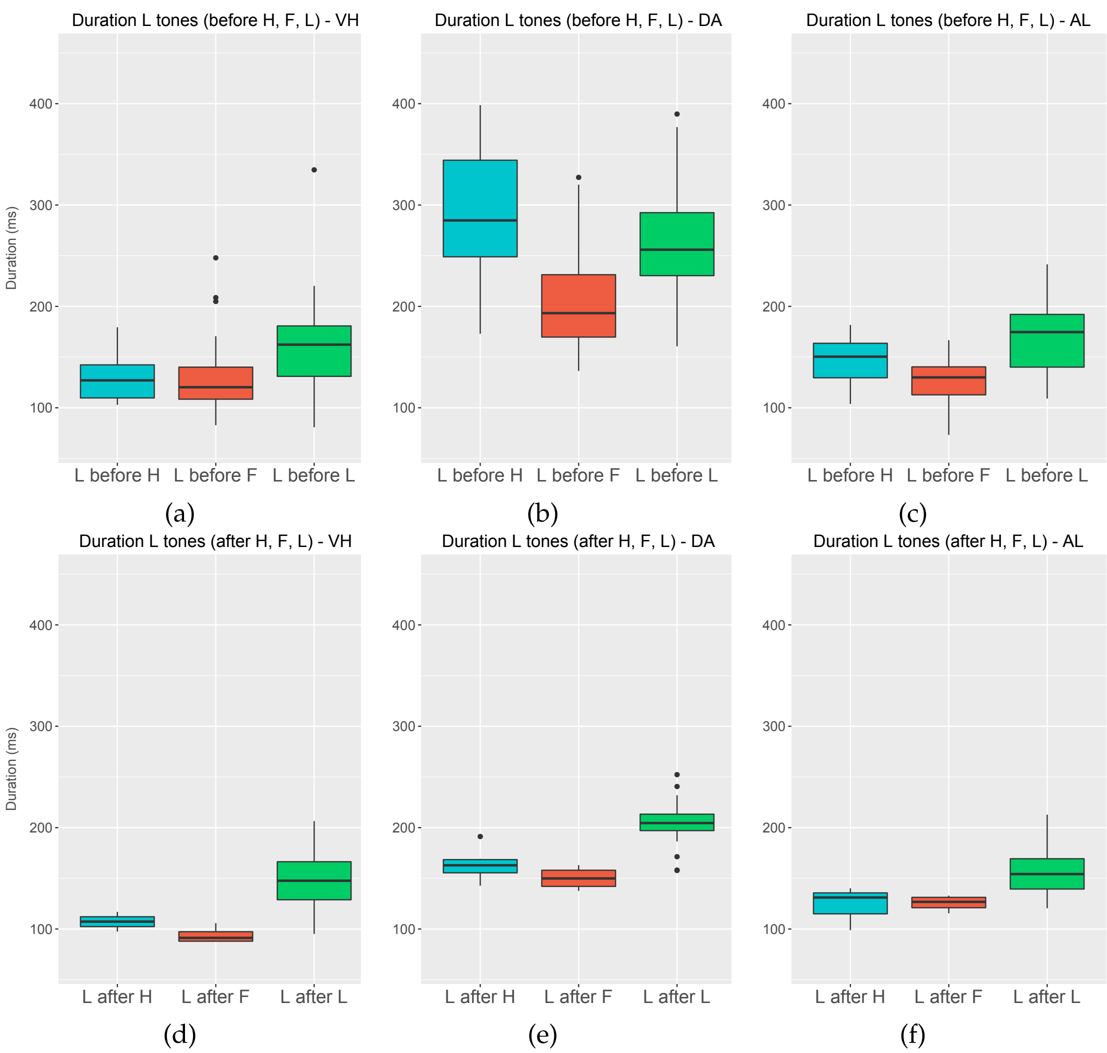


Figure 6.12: *Duration (ms) for Low tones preceding and following High, Low and Falling tones in disyllabic words (for the vocalic portion of the syllable), for each participant.*

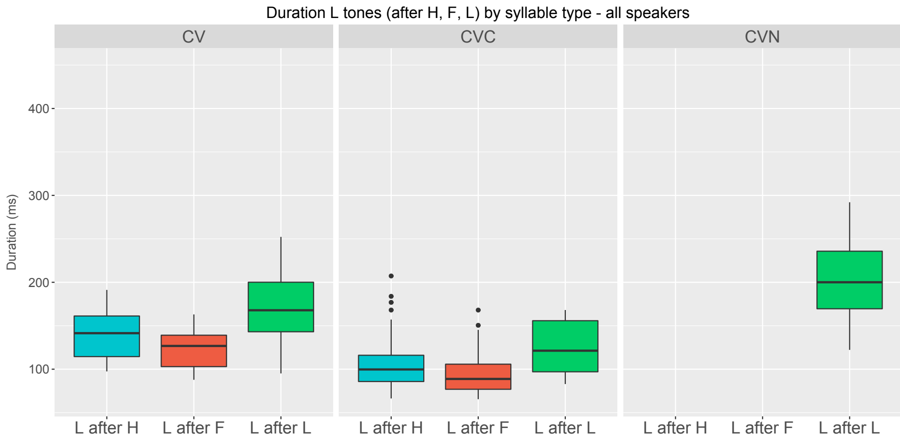


Figure 6.13: *Duration (ms) for Low tones following High, Low and Falling tones in disyllabic words, by syllable type (for the sonorant portion of the syllable rhyme), for all participants.*

6.5.3.3 Duration comparisons of H preceding and following H and L tones

In Figure 6.14, duration results for initial High tones preceding and following High and Low tones are shown. For initial syllables, patterns look very similar for High tones in each tonal context. A likelihood ratio test does not return a significant result (χ^2(1, N=230)= 0.44, p=0.51), suggesting that tone context does not have a greater influence on High tone duration than other random effects. For final syllables (CV only), some minor differences can be observed; the likelihood ratio test is significant (χ^2(1, N=139)= 4.14, $p<0.05$), and post-hoc tests show that High tones following Low tones are an estimated 30 ± 14 ms longer than High tones following other High tones.

Table 6.12: *Results of statistical comparisons between vowels with High tones (preceding and following High and Low tones) for duration values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS, ∅ = likelihood ratio test not significant).*

Duration comparison	result
High before High ∼ High before Low	∅
High after High ∼ High after Low	*

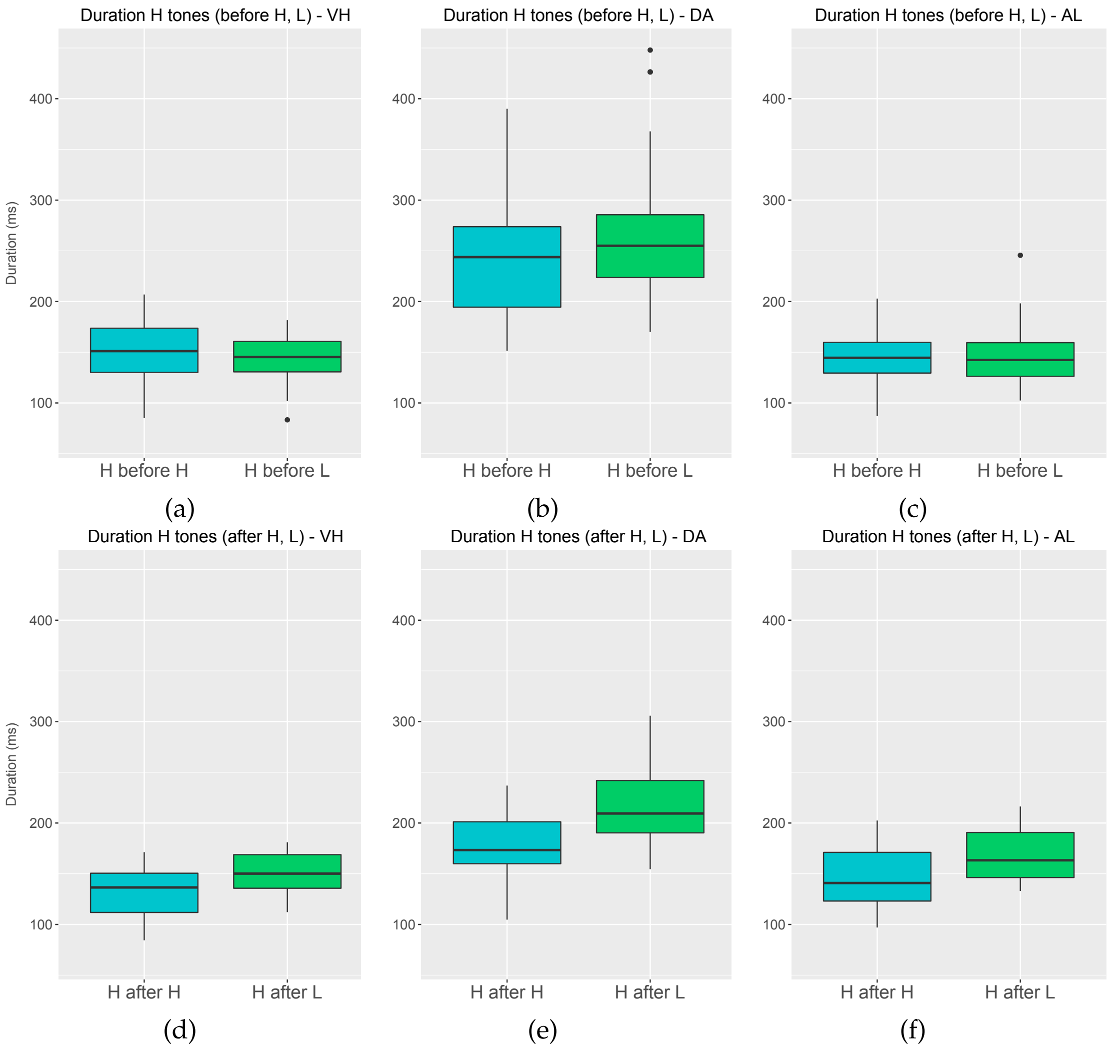


Figure 6.14: *Duration (ms) for High tones preceding and following High and Low tones in disyllabic words (for the vocalic portion of the syllable), for each participant.*

6.5.3.4 Duration comparisons for H and L tones preceding and following H and L tones

In Figure 6.15, the durations of High and Low tones adjacent to other High and Low tones are shown. For initial syllables, some minor differences can be seen in the distribution of values; a likelihood ratio test is significant ($\chi^2(1, N{=}161){=}\ 4.46$, $p<0.05$), and post-hoc tests indicate that Low tones preceding Low tones are an estimated 19 $\pm$ 9 ms longer than High tones preceding High tones. Minor differences can also be observed for final (CV only) syllables; a significant result is obtained from the likelihood ratio test ($\chi^2(1, N{=}180){=}$ 3.57, $p<0.05$), and post-hoc tests point towards duration values being an estimated 18 $\pm$ 9 ms higher for Low tones following Low tones compared to High tones following High tones. Though significant, these estimated differences are not particularly large, and are smaller than other significant duration differences noted in the preceding sections.

Table 6.13: *Results of statistical comparisons between vowels with High and Low tones (preceding and following High and Low tones) for duration values (***=p<0.001, **=p<0.01, *=p<0.05, - = NS, ∅ = likelihood ratio test not significant).*

Duration comparison	result
High before High ∼ Low before Low	*
High after High ∼ Low after Low	*

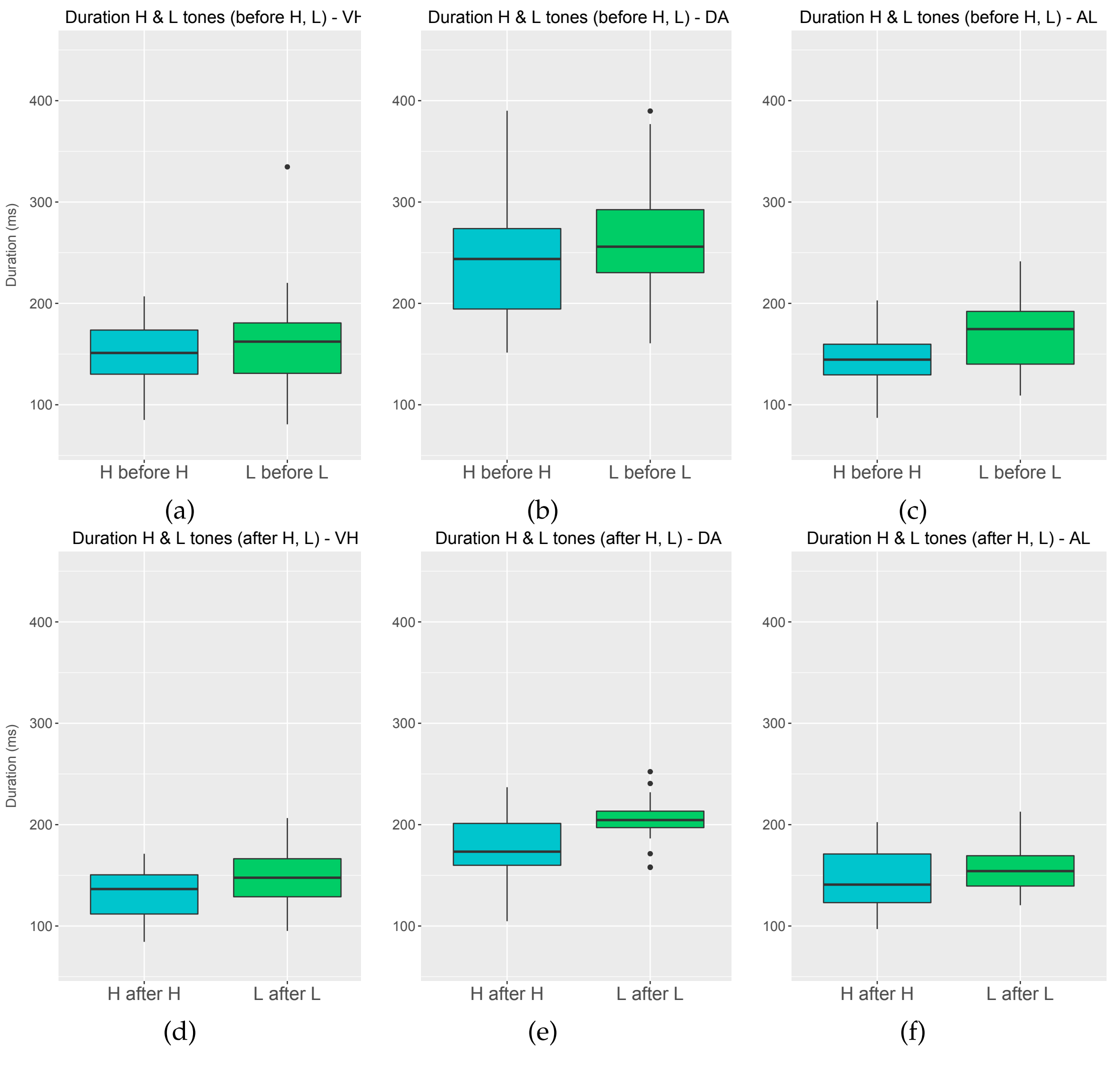


Figure 6.15: *Duration (ms) for High and Low tones preceding and following other High and Low tones in disyllabic words (for the vocalic portion of the syllable), for each participant.*

6.6 Discussion

6.6.1 Acoustic correlates of tone categories

Both hypotheses tested in this chapter relate to Research Question 5: "What are the phonetic characteristics of lexically contrastive tones on nouns in Lopit?" The first hypothesis, given in 6.3, focuses on evidence for tonal contrasts, and states that there are three phonemic tones in Lopit, comprising a High level tone, Low level tone, and Falling contour tone. Findings presented in 6.5 based on citation data provide strong supporting evidence for this hypothesis, and indicate that, combined with evidence put forward in Chapter 3, a phonological analysis of three lexical tones is appropriate for at least the Dorik dialect of Lopit. Results pertaining to this hypothesis are those which compare putative High, Falling and Low tones in initial syllables of disyllabic nouns, preceding a Low tone, and in final syllables of disyllabic nouns, following a Low tone, on the basis of fundamental frequency and intensity measures at three points in the rhyme (6.5.1.1, 6.5.2.1), and the duration of the vocalic portion of each syllable (6.5.3.1).

These results indicate that fundamental frequency is a major correlate of tone category in Lopit, as predicted. High and Low tones are differentiated by the High tone having significantly higher f0 values across the rhyme of initial and final syllables (at 25%, 50% and 75%). The Falling tone is clearly a contour tone, transitioning from high to low targets in terms of f0 values. It is differentiated from the Low tone by higher f0 values early in the rhyme (25% and 50%) in initial and final syllables, and compared to the High tone, the Falling tone is differentiated by lower f0 values later in the rhyme (at 50% and 75%) in initial and final syllables. The estimated difference between High and Low tones across the rhyme is 18–19 Hz according to statistical results (2–3 semitones with reference to individual speaker means), and in final syllables the difference ranges from 17 to 34 Hz as the Low tone falls more steeply in this position (2–5 semitones). In initial and final syllables, the Falling tone begins with values similar to the High, and is 15–17 Hz higher than the Low at 25% (2 semitones), and finishes with values similar to the Low, and is around 20–32 Hz lower than the High (2–3 semitones). These differences are within perceptible ranges (t'Hart, Collier & Cohen, 2006).

The differences in fundamental frequency for tones are expected, given that pitch is described as the major auditory correlate of tone categories in African languages, and in languages with phonemic tone more generally (Pike, 1948; Welmers, 1973, pp. 77–115; Yip, 2002). Results are very consistent across the three speakers who participated in this experiment, and it is clear that they are following similar patterns in terms of tone production. As discussed in 6.2.4 and by other researchers, such as Pulleyblank and Allen (2013), there is a scarcity of research reporting the fundamental frequency characteristics of tone categories in African languages; for languages within the Nilotic family, detailed findings have been reported for varieties of Western Nilotic languages Dinka and Shilluk in recent work by Remijsen and colleagues (e.g. Remijsen, 2013; Remijsen & Ayoker, 2014), but for languages of the Southern and Eastern branches of Nilotic, these are joined only by some preliminary analyses pertaining to intonation in Maa (Baltazani, 2002). These results provide quantitative evidence that differences in fundamental frequency are present in the acoustic signal for tones in Lopit, and lay the groundwork for future perceptual work examining the ways in which listeners attend to these cues.

Intensity and duration measures were also included, given that there is crosslinguistic evidence that differences in these may correlate with different tone types (though the phonetic correlates of tone in African languages beyond f0 are rarely discussed), as well as the possibility that these measures may be drawn on as cues to metrical prominence. Findings based on the present data are mixed, though speaker behaviour is reasonably consistent. For intensity, as indicated by RMS amplitude, likelihood ratio tests of values for High, Falling and Low tones in initial syllables returned no significant results, indicating that tone category does not have a more substantial effect on intensity differences than other factors in the analysis. Recalling that the data were drawn from words produced in isolation, and that the word-initial syllables were therefore also utterance-initial, this is not particularly surprising. In final syllables, likelihood ratio tests were significant, and there were significant differences between Falling and Low tones at 25% and 50%, and High and Low tones at 50% and 75%, with the Falling and High having values an estimated 3 dB higher than the Low. These findings are broadly compatible with observations elsewhere of correlations between high f0 values and high intensity for tones (e.g. Zee, 1978; Whalen & Xu, 1992; Fu & Zeng, 2000), though as for other languages, it is unlikely to be a major cue. However, whether or not these differences have salience for Lopit listeners, as speculated by Baltazani (2002) for Maa, remains to be seen.

Though there are some observable patterns in plotted duration values, such as a tendency for vowels with Falling tones to have longer durations, likelihood ratio tests for High, Falling and Low tone data in initial and final syllables are not significant, indicating that tone does not have a greater effect than other factors on the duration characteristics of vowels bearing different tones. Closer inspection of the data suggests that the difficulty in constructing a balanced dataset with available lexical data is a particular limitation in this case, especially in relation to results for Falling tones; clearer patterns may be found in later work as the linguistic record of Lopit continues to expand. However, some interesting results emerge when looking at contextual variation in tones. These are discussed further in 6.6.2, but include observations that the duration of a Low tone also appears to be adjusted depending on which tone it abuts, with Low tones both preceding and following Falling tones having duration values 47 ms lower than those preceding and following other Low tones. Speculation that the Falling tone could be longer than other tones (Turner, 2001, p. 44) may not, then, be unfounded; instead of the syllable bearing the Falling tone showing reliable duration differences, the salient cue may be the duration of the Falling tone relative to adjacent syllables, with the adjacent syllables undergoing the necessary modifications.

Overall, these results support the hypothesis that Lopit has contrastive High, Low and Falling tones, and that differences in f0 values relative to one another are a major correlate of the distinction. The investigation of other measures shows that while intensity and duration cannot be ruled out as additional cues, their influence according to tone category is not substantial enough over other factors in the present data. However, these measures may be relevant to Lopit phonological patterns in others ways, as discussed further below. These findings corroborate previous researchers' observations that the Lopit tonal inventory includes a High, Falling and Low tone (Vossen, 1982; Turner, 2001; Stirtz, 2014b); possible reasons for Vossen's suggestion of a Mid tone are addressed below.

6.6.2 Contextual variants of tones

The second hypothesis given in 6.3 focuses on realisations of the same tone in different contexts, and states that contrastive tones have different phonetic characteristics depending on adjacent tones. In general, results provide supporting evidence for this hypothesis, though there are some complexities in the findings. Findings pertaining to this hypothesis are those throughout 6.5 comparing realisations of the High and Low tones in different tonal contexts on the basis of fundamental frequency, intensity, and duration.

As discussed above, when looking at High, Falling and Low tones on the basis of fundamental frequency, it is clear that the proposed tones are distinct from one another when they occur in comparable tonal environments, namely when each tone precedes or follows a Low tone. However, results presented in 6.5.1.2, 6.5.1.3 and 6.5.1.4 show that the f0 characteristics of High and Low tones depend on the tonal context in which they occur.[2] For example, fundamental frequency values for the initial High tones are an estimated 7–9 Hz higher when they occur initially in H.L words than in H.H words (1 semitone, with reference to individual speaker means). In final syllables, though there are no differences between High tones after High and High tones after Low at 25%, High tones after Low are 6–8 Hz higher later in the rhyme (ranging from less than 1 up to 2 semitones for individual speakers). For Low tones, likelihood ratio tests are not significant for data in initial syllables, but in final syllables, Low tones following a High are 8–10 Hz lower than Low tones following another Low (1–2 semitones). Low tones are also 9–10 Hz lower (1–3 semitones) when following Falling tones than when following other Low tones in F.L words (though there were no significant differences at 75%).

Overall, these f0 results are indicative of tonal dissimilation; High tones are higher when adjacent to Low tones than when adjacent to other High-toned syllables, particularly if they occur initially, in which case the following Low tones are also lower, suggesting that High and Low tones are maximally distinct in H.L words. Low tones following Falling tones show a similar lowering. These findings can be broadly interpreted as increased contrast between the Low, High and Falling tones when they neighbour tones

[2] The realisation of Falling tones in different environments receives limited discussion here, as Falling tones only occur adjacent to Low tones in the current data.

of a different, rather than the same, tonal category, and may be indicative of differences in the prominence of some syllables over others, discussed further below on the basis of other cues. These f0 patterns may be behind Turner's impression that high tones were noticeably higher in particular contexts (Turner, 2001, p. 47). In ongoing work, analyses involving words of different lengths and a range of morphological structures would offer additional insights.

The magnitude of the difference between High tones in different contexts is smaller than f0 differences between contrastive tones, but likely perceptible, as are the differences between Low tones in different contexts. While phonetic evidence for the conditioning effects of tonal context has only infrequently been sought for languages of the African continent, similar local effects have been found, for example in Yoruba; Connell and Ladd (1990, pp.17–19) and Laniran and Clements (2003) observe that High tones immediately preceding Low tones are substantially higher than High tones preceding other High tones, and that this both interacts with and perhaps enables downstep processes for sequences of High tones alternating with Low tones. The varying realisation of High tones in Lopit also points to a possible reason why Vossen (1982) proposed a Mid tone for the language, based on his transcriptions of a 157-item wordlist. If, when a word bears all High or all Low tones, the tones tend to be less high or less low, respectively, the perception of a possible mid-range tone in such instances is understandable. For example, Vossen (1982, p. 130) transcribes 'sun SG' with Mid tones (unmarked), as [xɔlɔŋ], corresponding to Low-toned [xɔ̀lɔ̀ŋ] for the Dorik participants in this study, and similarly recorded as [hɔ̀lɔ̀ŋ] for the Ngutira dialect by Stirtz (2014b, p. 40). It may also be more difficult for non-native ears to confidently distinguish whether words have all High or all Low tones; the direct comparison of High and Low tones in H.H and L.L words shows that while they are significantly different, the difference at least in initial syllables is smaller than when High and Low tones are both followed by Low tones (an estimated 9–12 Hz, or 1–3 semitones across speakers), though in final syllables the size of the difference is much the same (16–27 Hz, or 2–5 semitones). However, in consultations with native speakers, including using the Toney software mentioned earlier (Bird & Lee, 2014), they are easily and consistently categorised.

When making further comparisons between initial High tones in H.L and H.H words, and between final High tones in L.H and H.H words, likelihood ratio tests are not significant for intensity (6.5.2.3), but for duration (6.5.3.3), vowels with High tones are an estimated 30 ms longer following a Low tone than they are following a High tone. The difference is minor, but could potentially support the greater prominence High tones are afforded on the basis of somewhat higher f0 values in this context. For Low tones in initial and final contexts, likelihood ratio tests are not significant for intensity values in initial syllables (6.5.2.2), but in final syllables, values are lower if the Low tone is preceded by a Falling tone (by 4–6dB) or High tone (by 3–4dB). As noted above, Low tones were also observed to have lower f0 values in this context. Intensity differences can also be seen in the example spectrograms and corresponding waveforms in Figure 6.2. Some interesting results are also found for Low tone duration values (6.5.3.2). In L.H, L.F and L.L words, the duration of initial Low tones differs; as noted above, Low-toned vowels are an estimated 47 ms shorter when they precede a Falling tone than when they precede another Low tone, and are also an estimated 35 ms shorter when preceding a Falling tone compared to a when they precede a High tone, suggesting that the anticipation of a Falling tone in a following syllable compels Lopit speakers to reduce the duration of the preceding Low tone. For final Low tones in H.L, F.L and L.L words, vowels with Low tones following a Falling tone are 47 ms shorter than vowels with Low tones following other Low tones, and interestingly vowels with Low tones following a High tone are 41 ms shorter than when following another Low, suggesting Low tones may be generally less salient when adjacent to High or Falling tones.

Although likelihood ratio tests were not significant when directly comparing the duration of vowels with High, Falling and Low tones, despite apparent differences in the spread of duration values, these results indicate that tone duration is certainly worthy of closer investigation in Lopit and other African languages. The crosslinguistic tendency for contour tones to co-occur with longer duration values, either through phonological restrictions on where they may occur (e.g. syllable type), or phonetic effects on the tone-bearing unit (e.g. lengthening of the syllable nucleus), is well established (Gordon, 2001; Zhang, 2001), but adjacency effects on tone duration have received limited attention, given that inherent tone duration has in itself received limited attention. However, it has long been recognised in studies of segmental duration that compensatory lengthening and shortening of segments can occur as they interact with neighbouring segments (e.g. as discussed in 5.2.5), perhaps to maintain preferred overall word durations, and if different tones have different durational requirements, it is entirely likely that a similar balancing act between the durations of different syllables will take place. This would be a particularly interesting research direction for Lopit but also in studies of tone systems more generally.

With reference to auditory correlates, then, it seems that Low tones are likely lower in pitch, less loud, and shorter when they follow High and Falling tones than when they follow other Low tones, and at least shorter preceding High and Falling tones. High tones appear to be highest in pitch when they precede or follow Low tones, and are also somewhat longer when they follow Low tones. The observed variations in fundamental frequency, intensity and duration may help to enhance differences between neighbouring dissimilar tones, and in particular may afford High and perhaps Falling tones greater prominence in relation to other tones. They may also be indicative of higher-level prosodic structures. These findings provide support for the hypothesis that lexically contrastive tones have different phonetic realisations depending on where they occur in the word and which tones occur in adjacent syllables, and also show that there is a need for more comprehensive work on the various interacting factors affecting tonal realisation in Lopit and other Nilotic languages.

6.7 Chapter Summary

This chapter has investigated two hypotheses relating to Research Question 5, “What are the phonetic characteristics of lexically contrastive tones on nouns in Lopit?”. Convincing evidence was found for the first hypothesis; results indicate that fundamental frequency is a robust correlate of the three proposed Lopit tone categories, High, Falling, and Low, supporting impressions that these are contrastive and that pitch is a major cue. Some minor differences were observed on the basis of other measures, but were most relevant to the second hypothesis, that Lopit tones have different phonetic realisations in different contexts. Key findings relating to this hypothesis were that High tones are highest in fundamental frequency when they neighbour Low tones (compared to when they neighbour other High tones), and that the duration of Low tones appears to be adjusted depending on which tones occur in adjacent syllables, being shortest when they precede or follow a Falling tone. These results provide the first data on the phonetic realisation of tone in Lopit, and the confirmation of three tones is a timely contribution informing ongoing morphosyntactic analyses as well as phonological understandings. The results also raise interesting questions regarding possible metrical patterns in Lopit; findings for f0 and particularly intensity and duration suggest syllables are afforded different prominence depending on neighbouring tones and position in the word, and this would be well worth further exploration with words of different lengths, different morphological structures, and in different utterance contexts. More generally, the phonetic data presented in this chapter suggest that illuminating patterns may be found if measures beyond f0 are included in analyses of tone in African languages. In the following chapter, Chapter 7, these findings and some of the possibilities for future work are drawn together with the quantitative insights of Chapter 4 and Chapter 5 as part of a concluding discussion.

Chapter 7

Situating Lopit Phonetics and Phonology in the Nilotic Context and Beyond

7.1 Introduction

This thesis constitutes an investigation of the sound system of Lopit, an Eastern Nilotic language of South Sudan for which the linguistic record was, until recently, quite limited. The primary aim of this project has been to produce a phonetically-based description of Lopit phonology, and in doing so, to demonstrate the crosslinguistic insights to be gained from quantitative examinations of segmental and tonal phenomena in Nilotic languages, and the possibilities for including such examinations in the earlier stages of language documentation. Despite the wealth of typologically interesting phonological phenomena noted for African languages, relatively little phonetic data has been brought to bear on discussions of African phonological systems, but there is much potential for phonetic research on these languages to advance understandings of the strategies used, across languages, to create meaningful distinctions between speech sounds, and to develop more comprehensive understandings of linguistic relationships. The present findings for Lopit join a small but growing body of work illustrating the value of phonetic research in the description of Nilo-Saharan languages, while also contributing to ongoing work investigating various other aspects of Lopit linguistic structures.

Through the phonological analyses presented in Chapter 3 combined with the first phonetic analyses for Lopit, presented in Chapter 4, Chapter 5, and Chapter 6, this thesis provides the most comprehensive description of Lopit phonology to date, with a particular focus on the Dorik dialect of the language. The findings presented here are based on extended data collection with a small community of Lopit speakers in Melbourne, Australia, which since the early 2000s has been home to many members of the South Sudanese and Sudanese diaspora. The primary aim of the project, and the five specific research questions put forward in 1.5.2, were approached first via the collection of lexical and morphosyntactic data with Lopit speakers. With reference to these data, a number of hypotheses were developed regarding the Lopit segmental and tonal inventory, and followed by quantitative investigations testing the phonetic evidence for selected contrasts proposed in Chapter 3, relating to the vowel system and 'Advanced Tongue Root' distinctions, the possibility of length distinctions among palatal and labial-velar glides, and tonal distinctions. Key findings are summarised in the following sections, and some of the implications noted. An advantage of this work is that the insights from the phonological analyses and the different phonetic investigations are based on members of the same group of participants. The focus of this work has been on specific contrasts within the Lopit phoneme inventory, but the different types of results drawn from the same group of speakers also offer greater opportunity to consider how the details of specific contrasts may contribute to the workings of the sound system as a whole. These considerations inform the various possible directions for future research which are discussed throughout this chapter.

7.2 Segmental and Tonal Contrasts in Lopit

In Chapter 3, analyses of the segmental and tonal phonology of Lopit were presented, in order to address RQ1, "What are the major phonological contrasts in Lopit?" As noted, data presented therein primarily focus on the Dorik dialect of Lopit. Based on a lexical database of over 2,500 entries, together with transcriptions of elicited and narrative language data, evidence is presented for 27 consonant phonemes, outlined in 3.3. These include voiced and voiceless stops at four supralaryngeal places of articulation, corresponding nasals, and a word-final glottal stop. Voiceless labiodental, alveolar and velar fricatives are also noted, as well as a postalveolar fricative which appears to be a free variant. Two rhotics, two laterals, and four glides are also observed. A notable feature of the Lopit consonant inventory is the proposed contrast between singletons and geminates, such as between alveolar consonants /t, d, n, l/ and /tː, dː, nː, lː/, and between a tap /ɾ/ and trill /r/. A length contrast is also proposed among the glides, which are suggested to comprise singletons /w, j/ and geminates /wː, jː/.

A consonant inventory of this sort is fairly typical of the non-Bari Eastern Nilotic languages, as the typological overview in Chapter 2 has shown; there is no dental/alveolar contrast, as is characteristic of Western Nilotic languages (2.2.1), nor is there a single (voiceless) stop series, as is common in Southern Nilotic, or a third, implosive stop series, as found among the Bari languages in the Eastern Nilotic family (2.2.3). Though it is a typologically uncommon contrast, the distinction between 'long' or 'strong' /wː/ and /jː/ compared to /w/ and /j/ has been noted for a number of Eastern Nilotic languages in the Lotuxo-Maa group, as has the contrast between alveolar /ɾ/ and /r/. Phonetic findings for Lopit glides are discussed in 7.4. As noted in 2.2.4, the other length contrasts at the alveolar place of articulation appear to be more restricted to languages of the immediate Lotuxo family, as does the final glottal stop, though a glottal consonant of some sort, often word-initial, has been noted elsewhere in Nilotic (2.2.1). The Lopit fricative inventory is not unlike that proposed for a number of related languages, but also appears to be a source of particular variation in Eastern Nilotic, especially with regard to the relationship between fricatives and voiceless stops (2.2.2). Closer examination of the distribution and phonetic characteristics of obstruents across Eastern Nilotic languages will likely offer more detailed insights into the development of different inventories across the family.

These findings are broadly similar to previous observations for Lopit consonants. Differences are, for the most part, likely due to the more extensive lexical and morphosyntactic data available to inform the present analyses. For example, Vossen (1982) does not note /dː/, /nː/, /lː/, or the contrast between /ɾ/ and /r/, but as these (impressionistically) appear to have a lower functional load than the contrasts between /wː, w/, /jː, j/ and /tː, t/, it is not surprising that relevant examples were not found in a 156-item wordlist. Vossen (1982) is also uncertain of the status of some fricatives in relation to stops, and again, possible interpretations were likely limited by the available data. In the present work, there are indications that the status of some contrasts may differ in nouns compared to verbs, and also depend on the word position, with the initial consonant of a verb stem being a highly salient location for phonemic distinctions. The relationship between word class, word position, and the status of consonantal contrasts would be well worth further exploration as documentation continues, as it seems there may be some clues to processes of change which have taken place, or are taking place, in Lopit. Furthermore, a corpus study of phoneme frequency in samples of naturally-occurring speech would be illuminating; it has been suggested that the functional load of some consonantal contrasts is marginal, as for /dː/, or highly restricted by environment, as for /ʔ/, and the ability to quantify these tendencies and further explore distributional patterns would deepen the understanding of how the consonant segments work together as part of a system.

Some other differences are likely due to varying analytical preferences, for example analyses of geminate consonants as sequences of identical segments, rather than single long segments (Stirtz, 2014b), or due to differing impressions of the articulatory nature of consonants, for example proposals of /h/ instead of /x/ (Stirtz, 2014b), or /tʃ/ and /dʒ/ instead of /c/ and /ɟ/ (Turner, 2001). The articulatory nature of Lopit coronal contrasts would be an excellent topic for further study, given that where this is discussed across Eastern Nilotic languages, there are varying descriptions of the active and passive articulators, and this has so far only been investigated using static palatography with a speaker of Kisongo Maasai (Epstein & McCrary, 2002). However, it is clear that there are also some dialectal differences in Lopit, including in the coronal space (Stirtz, 2014b). More detailed exploration of dialectal differences is an obvious direction for future research on the sound system of Lopit. While Lopit speakers tend to conceive of the north-south series of dialect areas as ranging from more conservative to less conservative, where less conservative also reportedly corresponds to more Otuho-influenced, some have also suggested that settlement times and patterns are not the same for communities in different Lopit regions, so the relationships between dialects may well be more complicated (Murahashi, p. c., and as noted in 1.4.1). Certainly there is scope for the understanding of the relationship between Lopit dialects, and between Lopit and neighbouring languages, to be improved though the collection of oral histories and other research beyond linguistics.

For the Lopit vowel system, evidence presented in 3.4 points towards nine contrastive monophthongs: /i, ɪ, e, ɛ, a, ɔ, o, ʊ, u/. Seven diphthongs were also observed. It was proposed, based on various types of evidence, that these vowels could be divided into two sets, and that the phonological feature 'Advanced Tongue Root', widely applied in the description of African languages (2.3.1), might be the basis of this distinction. The label [+ATR] was adopted for the monophthongs /i, e, o, u/ and the label [-ATR] for the vowels /ɪ, ɛ, a, ɔ, ʊ/, and it was noted based on auditory impressions that vowels in the former set have a closer quality than their counterparts in the latter. An [ATR] distinction was also suggested to occur among the diphthongs, though likely with a limited functional load. The phonetic nature of monophthong distinctions emerged as a topic of particular interest, and findings are discussed in 7.3. In 3.4.3, a process of vowel harmony was also described, by which [+ATR] vowels to the right edge of the word prompt a leftward-spreading change from [-ATR] to [+ATR] vowels, but which is interrupted by /a/ (which also lacks a [+ATR] counterpart). Similar processes are observed across Eastern Nilotic languages. While both Vossen (1982) and Turner (2001) note their impressions that a vowel harmony process of some sort appears to be at play in their Lopit data, the analyses in the present study constitute the first description of its workings in Lopit. In addition, other significant phonological processes affecting vowels, such as mid-vowel assimilation, are also described.

The nine-vowel monophthong inventory and associated harmony processes are, as for the consonant inventory, characteristic of the non-Bari Eastern Nilotic languages, as the overview in 2.3.2 shows. While some of the Bari languages, as well as some of the languages of the Western and Southern Nilotic branches, have ten-vowel systems, including a [+ATR] counterpart to /a/ (such as /ə/ or /ʌ/), these are not typical of languages in the Lotuxo-Maa and Teso-Turkana groups within Eastern Nilotic. Furthermore, there is no evidence for a length contrast among Lopit vowels, unlike the two-way length distinctions common among Southern Nilotic languages, and up to three-way length distinctions found among Western Nilotic languages (2.3.4). There are also no signs of phonatory contrasts such as those noted for some Western Nilotic languages in the Dinka-Nuer branch, nor for voiceless vowels as described for some languages in the Teso-Turkana branch of Eastern Nilotic (2.3.3).

These observations for the Lopit vowel system are similar to those put forward by Vossen (1982) and Turner (2001), though both were uncertain about the possibility of a [+ATR] counterpart to /a/. However, these results differ from Stirtz's (2014b) findings of a five-vowel system, comprising /i, ɛ, a, ɔ, u/, with no ATR contrast. These differences further underscore the need for more detailed explorations of dialectal differences in Lopit; though the data presented by Stirtz (2014b) were collected with speakers of five dialects, the Ngutira dialect was a particular focus for the phonological description, and it is possible that the linguistic patterns for that speaker, and perhaps others, represent a change which is unevenly distributed across Lopit-speaking communities. A reduction in the number of contrasts in a former ATR system would not be uncommon (Casali, 2008), and this has occurred to at least some extent in some other Nilotic languages, as noted in 2.3.

As for the consonant inventory, corpus studies would help to further understand the distributional patterns of vowel segments in Lopit. There are many comments in the literature about [+ATR] vowels being more marked, and less frequent, as well as regarding their propensity to co-occur with one another, but these have generally not been followed up with any comprehensive and quantitative analyses. These sorts of investigations are likely limited by the availability of suitable corpora accompanied by the necessary level of linguistic description. However, this would seem to be a practical avenue of research seeking to understand the functional load of ATR contrasts. While work so far, including that discussed further below for Lopit, has focused on establishing the distinctions between vowel segments, observations that [+ATR] and [-ATR] vowels are less likely to co-occur with one another than to occur with vowels of the same specification raises questions about to what extent listeners depend on individual vowels in word identification, or whether the segmental company kept by these vowels also has a significant role.

A tonal inventory with contrasts between High, Low and Falling tones was proposed for Lopit, and evidence was presented to show that these contrasts are used for lexical distinctions, and also have grammatical functions. As noted in 3.5.1, these distinctions likely have a greater grammatical than lexical functional load in Lopit; minimal pairs are uncommon, and where they occur, they are often of different word classes. Previous researchers, such as Turner (2001), have similarly proposed High, Low and Falling tones with lexical and grammatical significance. Vossen (1982) also suggests a Mid tone, and Stirtz (2014b) suggests an additional Rising tone which is likely a notational rather than phonemic variant. From the present data, the Falling tone is described as having an unbalanced distribution; it is contrastive in all word positions and across syllable types, but at least among nouns it is particularly common word-finally, and in some specific cases it appears to originate from the coalescence of differently-toned neighbouring vowels. The understanding of the distribution of the Falling tone, and Lopit tonal patterns more generally, would also benefit from corpus analyses, and given the reported dialectal differences in segmental and tonal patterns as well as inflectional patterns, noted in 1.4.3, the distribution of the Falling tone may also vary across dialects. High, Low and Falling tones are typical of Eastern Nilotic languages, though as noted in 2.4, in some cases the Falling tone is a positional variant, and in some cases its status is not clear. A Mid tone has been inconsistently observed for some Eastern Nilotic languages, and seems likely to be a variant of High tones in at least some cases. Phonetic findings for Lopit tonal contrasts are discussed in 7.5.

Grammatical uses of tone are particularly deserving of further research in Lopit. Previous work on Lopit (Vossen, 1982; Turner, 2001; Stirtz, 2014b) has noted, as in the present study, that tone likely has a more significant role grammatically than lexically, and ongoing investigations of Lopit morphosyntactic patterns show that tone has a number of functions (Moodie, in progress), some of which are noted in 3.5.2. Insights from both morphosyntactic as well as phonological evidence are clearly crucial to understanding how tone works as part of the linguistic system, and this understanding can continue to be developed as new data emerge. In particular, targeted investigations of the interactions between tone and word and syllable structures will likely be revealing. For example, in the nominal morphology, the tone patterns used for nominative case-marking appear to be to some extent lexically specified, but also show signs of some influence from tonal patterns used across the word in the unmarked forms (as discussed in 3.5.2

and Moodie & Billington, 2015), and in the verbal morphology, there are indications that patterns of aspectual marking, which can include tone changes, are influenced by the CV structure of the verb stem (Moodie, in press). These interactions contribute to the challenges associated with the description of tone in Nilo-Saharan languages. Though impressions of the greater grammatical importance of tone are often reported for Nilo-Saharan languages, as noted in 2.4.1, most Nilo-Saharan tone systems have been poorly documented. For Otuho, the most closely-related language to Lopit which has been the subject of an extended grammatical description, tone is not even marked in the grammatical description which still serves as the primary reference on the language (Muratori, 1938). For Lopit, while there remains much to be done, the present work complements concurrent morphosyntactic research and further develops the understanding of Eastern Nilotic tone systems.

7.3 Vowels and 'Advanced Tongue Root'

In Chapter 4, proposals for the Lopit monophthong inventory were tested via two production experiments. The first related to RQ2 "What are the acoustic correlates of vowel contrasts found in Lopit?", while the second related to RQ3, "What sorts of articulatory mechanisms are involved in producing Lopit vowel contrasts?" Four hypotheses were developed, with a particular focus on contrasts which, with the appropriate evidence, would be a key part of establishing the overall vowel inventory. The first hypothesis related to the acoustic evidence for a contrast of the sort typically described (for African languages) as involving the phonological feature 'Advanced Tongue Root'. As noted above, in Chapter 3, the proposed monophthong inventory was divided into two sets of vowels separated by a putative 'Advanced Tongue Root' distinction, with relevance for vowel harmony processes, including pairs of [+/-ATR] vowels of a similar height, backness and rounding: /i, ɪ/, /e, ɛ/, /o, ɔ/, and /u, ʊ/. The articulatory gestures distinguishing these sorts of [+/-ATR] pairs have been the subject of much debate in the phonological literature and of various findings and interpretations in the articulatory literature, and as such the gestural differences for Lopit vowels were the focus of the second hypothesis.

As noted in 4.2.4, for many languages with [ATR] contrasts, it has also been observed that the [-ATR] close vowels /ɪ/ and /ʊ/ and the [+ATR] mid vowels /e/ and /o/ are auditorily very similar, sometimes leading to mistakes in the phonological analyses of individual languages, and also that they often show acoustic overlap, so the proposed distinctions between these are the focus of the third hypothesis. Finally, the possibility of a [+ATR] counterpart to [-ATR] /a/ was investigated, given previous speculation about this for Lopit and related languages.

Acoustic analyses of 1,200 vowel tokens, collected with four participants, provide quantitative evidence that there are distinctions for vowels in the pairs /i, ɪ/, /e, ɛ/, /o, ɔ/, and /u, ʊ/ as produced by the Dorik Lopit participants in this study. The [+ATR] vowels, which in Chapter 3 were impressionistically noted to have closer qualities, all have significantly lower F1 values than their [-ATR] counterparts, by an estimated 67–126 Hz. This finding is not particularly surprising; where acoustic analyses have taken place, F1 is the most crosslinguistically reliable correlate of ATR category, as discussed in 4.2.4, and impressions of a closer compared to more open quality are widely noted for similar classes of vowels across Nilo-Saharan and Niger-Congo languages. However, the phonetic correlates of ATR category have been tested in very few Nilo-Saharan languages to date, and these results continue to develop the wider understanding of ATR, specifically among Eastern Nilotic languages, for which formant data across vowel pairs have so far only been presented for Maasai (Guion et al., 2004; Quinn-Wreidt, 2013) and Ateso (Lindau, 1975; Lindau et al., 1972), plus a small amount for Kuku (R. M. R. Hall & Creider, 1998). Mixed results were obtained for other measures, but this is also not surprising, given that the mixed results for measures other than F1 across other phonetic studies of ATR suggest that any secondary cues have more language-specific than general relevance. It can be concluded that differences in F1 constitute the primary acoustic correlate to ATR category in Lopit.

Some of the less consistent differences observed include those for F2, which, for Lopit [+ATR] front vowels /i/ and /e/, is higher than for [-ATR] front vowels /ɪ/ and /ɛ/, a finding noted in a number of other languages (e.g. Starwalt, 2008). Among the back vowels, for which F2 values for [+ATR] vowels in other studies may variously be lower than, higher than, or no different to those for [-ATR] vowels (despite the generalisation by Ladefoged and Maddieson (1996b) that [+ATR] back vowels tend to also have higher F2 values), the only difference in Lopit is that [+ATR] /o/ has lower F2 values than [-ATR] /ɔ/. When peripherality is measured using Euclidean distances, only [+ATR] /i/ and /e/ are shown to be more peripheral than their [-ATR] counterparts. Some F3 differences are observed for /e, ɛ/, but no duration differences are observed for any harmonic pairs. This is interesting in itself, given that the 'tense/lax' contrasts in Germanic languages, which draw on similar distinctions in vowel quality, are strongly associated with duration differences as well. Though future work may reveal minor differences, once more extensive lexical data permit the compilation of more controlled experimental datasets, it seems unlikely that either F3 or duration will have a significant role in signalling ATR contrasts in Lopit. While spectral emphasis measures hint at the possibility of a somewhat breathier vowel quality for [+ATR] vowels compared to [-ATR] vowels, if overall ATR category is treated as a main effect, a great deal of variability is also observed; no significant differences are found for the [+/-ATR] pairs of interest, though in tests for individual speakers, there is one participant for whom significant differences are observed.

The acoustic results also show that [-ATR] /ɪ/ and /ʊ/ are reliably distinct from [+ATR] /e/ and /o/, and that the correlates to the distinctions in these close/mid pairs are similar to those for the harmonic pairs. Significant F1 differences of an estimated 50 Hz separate both /ɪ/ and /e/ and /ʊ/ and /o/, which is a somewhat smaller than the observed difference for harmonic pairs, but likely salient. Both also differ on the basis of Euclidean distance measures, with the [-ATR] close vowels being more peripheral in each case. For /ɪ/ and /e/, differences in F2 and duration were also found to be significant. In addition to illustrating the acoustic distinctions for both the harmonic pairs and the close/mid pairs, these results show that it will be important for production research in this area to continue to include a number of different measures, in order to develop more comprehensive understandings of how contrasts might be signalled. While the F1 differences for both the harmonic pairs and the close/mid pairs appear robust in the present data, there is clearly scope for perception research to assess to what extent speakers rely on these as the primary cue, or whether they are also attentive to cues provided by other correlates. This has been the subject of speculation in some of the existing literature, particularly where acoustic results have been more variable across different pairs of vowels. Research of this sort is, however, particularly lacking in the literature on African languages, and given that the design of perceptual experiments necessarily depends on a reasonable level of description of the acoustic correlates in production, this is not surprising. As noted in 7.2, where future perception work does take place, it will also be necessary to consider to what extent the functional load of [ATR] distinctions is borne by individual segments, or assisted by the [ATR] quality of vowels in neighbouring syllables, given the tendency for words to have vowels sharing one or the other specification.

The acoustic results for [+ATR] vowels /i, e, o, u/ and their [-ATR] counterparts /ɪ, ɛ, ɔ, ʊ/ are supported by the articulatory findings presented in the same chapter, and which constitute the first articulatory data collected for an Eastern Nilotic language using ultrasound tongue imaging. These data complement early radiographic work on Ateso (Lindau et al., 1972), the only other available data on lingual gestures in Eastern Nilotic languages. In Figure 4.10 and Figure 4.11, Smoothing Spline ANOVA results for tongue contours at vowel midpoints were shown, comparing vowels in the four pairs. For the two Lopit speakers who participated in this experiment, the four proposed [+ATR] vowels have a tongue root position which is significantly anterior to that of corresponding [-ATR] vowels. For one participant, contours for tokens of /a/ in the environment of [-ATR] vowels were compared to tokens of /a/ in the environment of [+ATR] vowels, where, if there were a [+ATR] counterpart to /a/, it would be expected to occur. In this case the SSANOVA results show tongue contours which directly overlap. This supports the acoustic findings also comparing /a/ tokens in each environment, which showed that /a/ tokens in each context did not differ according to any acoustic or durational measure. This provides confirmation of the impressions reported in Chapter 3 that there are not two distinct 'open' vowels in Lopit, a matter which was not entirely clear in earlier work (Vossen, 1982; Turner, 2001), and which is often not certain, or not clearly stated, in descriptions of other Nilotic languages (Dimmendaal, 1988). As noted in 2.3.2, the presence of only one 'open' vowel is characteristic of the non-Bari Eastern Nilotic languages.

The evidence of lingual differences between [+ATR] /i, e, o, u/ and [-ATR] /ɪ, ɛ, ɔ, ʊ/ offers insights into the articulatory strategies used by Lopit speakers, and lends support to interpretations of the phonological feature [ATR] directly mapping to articulatory gestures (e.g. Hudu, 2014). However, a number of caveats are attached to this. Firstly, while mid-sagittal ultrasound imaging provides information about the tongue position, the complete details of the articulatory setting for [+ATR] compared to [-ATR] vowels in Lopit are not known. With reference to the results of articulatory studies of other African languages using cineradiography, MRI, and laryngoscopy (e.g. Lindau, 1979; Tiede, 1996, Edmondson et al., 2007), some inferences can be drawn; it is suggested that for Lopit vowels in the [+ATR] set, the more anterior tongue position revealed in the SSANOVA results likely co-occurs with an open epilaryngeal space and a neutral or probably lowered larynx position, while the more retracted tongue position observed for vowels in the [-ATR] set likely occurs with aryepiglottic constriction and a more raised larynx position, resulting in a reduced supraglottal space. The larger resonant cavity for the [+ATR] set corresponds to the lower F1 values observed. Given that no consistent acoustic or auditory evidence of phonatory differences between the two sets of vowels was observed, it is suggested that these articulatory postures are not accompanied by ventricular-fold vibration or changes to the glottal state for one set compared to another, which would be expected to offer more salient percepts of phonation differences (such as breathy voice). However, further instrumental work is required to verify the hypothesised differences beyond tongue root position for Lopit, specifically focusing on the precise contributions of both laryngeal and supralaryngeal gestures to the overall spectral differences. Such work would be of significant value in production studies of [ATR] contrasts more generally.

Furthermore, as discussed in 4.2.3 and elsewhere, different articulatory strategies may be used to achieve similar acoustic results. Previous research on some Nilo-Saharan languages, including Western Nilotic DhoLuo and Eastern Nilotic Ateso, indicates that changes in tongue body height may have a partial or substantial role in the production of ATR contrasts, but with effects on F1 that are the same as for languages with tongue root movement as the major observable gestural correlate. The extent to which different strategies may be used within a group of speakers of the same language remains an open question in articulatory studies of ATR distinctions; the articulatory component of the present study, with only two participants, is characteristic of the articulatory work which has been undertaken so far on ATR production, and there is a significant need for larger-scale work to assess both the intra- and inter-language limits of gestural variation. Following Ohala's (1996) arguments that "[s]peech perception is hearing sounds, not tongues", it is not clear that sharing an identical articulatory strategy should be a requirement, and this has implications for some of the debates surrounding how ATR should be interpreted as a phonological feature. However, it is expected that variation in ATR production across languages will occur within the range of articulatory elements available for speakers to draw on, which, as instrumental research has shown, allow for various configurations but crucially involve both the lower and upper vocal tract. Given that different combinations of the relevant articulatory elements give rise to acoustic effects which may range from being subtly to strikingly different, it is also expected that variation between speakers of the same language will be within a range which is a subset of the articulatory possibilities for ATR production, and which allows contrasts to be acquired and effectively maintained. Of course, large-scale work addressing both types of variation can only proceed from a reasonable level of existing linguistic description, and it is hoped that the present study therefore paves the way for some of these possibilities.

A question that has not generally been raised in studies of ATR distinctions, but which would be well worth exploring in future research, relates to the dynamic characteristics of vowels in ATR systems. Studies of vowel systems in languages which have received extensive scholarly attention, such as varieties of English, have in recent years been characterised by moves towards dynamic analyses of vowel production, for example looking at formant trajectories across the vowel, rather than just at vowel midpoints or targets (e.g. Docherty et al., 2015), with a range of interesting findings. These have not been explored in the present study, but may be revealing. Where a language is attested to have an [ATR] contrast, one of the two vowel categories is typically described as phonologically marked, and it has been suggested that this markedness corresponds to an articulation which departs from the rest position of the articulators in a more substantial way than for phonologically unmarked vowels (Hudu, 2014). If this is the case, the gestures required for vowels of each ATR category may also be differently timed in their implementation, and therefore have formant trajectories which differ in overall shape as well as at selected points. There may be also be dynamic differences for other reasons. More nuanced studies of these possibilities, with both acoustic and articulatory data, would further strengthen understandings of how ATR contrasts are maintained. Understandings of ATR distinctions would also benefit from investigation of the dynamics of ATR realisations in different prosodic and segmental environments, which, as greater descriptive attention is given to Lopit, and other under-described languages with attested ATR contrasts, will become increasingly possible.

7.4 Glides and Gemination

Chapter 5 focused on the phonetic evidence for selected proposals relating to the Lopit consonant inventory. In Chapter 3, contrasts between /t, d, n, l, w, j/ and /tː, dː, nː, lː, wː, jː/ were proposed, and it was suggested that the former be considered singletons, and the latter geminates (and that the contrast between /ɾ/ and /r/ could be considered part of the same pattern). The putative distinction between singleton and geminate labial-velar and palatal glides was highlighted as a feature of particular interest, given the typological rarity of length contrasts among glides (Maddieson, 2008). This relative rarity, or markedness, is suggested to be due to the spectral continuity of glides with neighbouring vowels hindering the accurate perception of constriction duration (Kawahara, 2007; Kawahara & Pangilinan, 2017). Some authors have taken this further and suggested that singleton and geminate glides may also be less reliably distinct in production, compared to geminates at other manners of articulation (Aoyama & Reid, 2006). These contrasts were the focus of RQ4, “What are the phonetic characteristics of contrastive glides in Lopit?” Three hypotheses were developed for testing. Given that the labels ‘singleton’ and ‘geminate’ had been applied based on impressions of length differences, measures of duration were especially pertinent to addressing this question, and were the focus of the first hypothesis. While differences in constriction duration are resoundingly correlated with singleton/geminate distinctions crosslinguistically, as discussed in 5.2.5, they have rarely been explored for singleton and geminate glides. Phonetic studies of length contrasts have also often reported a pattern of shorter durations for vowels preceding geminates, and this is the focus of the second hypothesis. As discussed in 5.2.8, existing descriptions of glides in Lopit and other Eastern Nilotic languages include impressions of possible articulatory differences in pairs of palatal and labial-velar glides, and the acoustic evidence for any additional or alternative correlates is the focus of the third hypothesis.

Results for 2,384 tokens of intervocalic Lopit glides, collected with five participants, show clear support for impressions of length differences between glides at the same place of articulation. Duration values for /wː/ and /jː/ are significantly and substantially higher than for /w/ and /j/. The geminate glides are overall 1.77 times longer than the singletons, which is comparable with the oft-quoted generalisation that geminates tend to be 1.5–3 times longer than singletons (Ladefoged & Maddieson, 1996b). In addition, there are significant duration differences between vowels preceding geminate compared to singleton glides. Vowels preceding singletons are overall 1.27 times longer than those preceding geminates, a pattern indicative of the pre-geminate shortening widely noted for other languages. Duration patterns across speakers and across the two pairs of glides are very consistent. This evidence provides quantitative support for the proposal that there is a contrast between glides at the same place of articulation, as also suggested by previous authors (Vossen, 1982; Turner, 2001; Stirtz, 2014b), and strongly suggests that duration is a major correlate to the contrast. These results also have wider significance, beyond being the first phonetic study of glides in Lopit, or indeed any Nilo-Saharan language. The findings join those for a very small number of languages (e.g. Persian, some Arabic varieties, three Austronesian languages) for which glide length contrasts have been experimentally tested (Hansen & Myers, 2017; Khattab & Al-Tamimi, 2014; Cohn et al., 1999; Aoyama & Reid, 2006). They also bolster arguments by Maddieson (2008) that conceptualisations of glides as having inherently short durations are problematic, in the face of accumulating evidence that they are viable hosts for length contrasts. Nevertheless, the crosslinguistic understanding of the phonetic implementations of glide length contrasts remains extremely limited, and there is a significant need for additional studies of this topic across a wide range of languages.

As noted, length contrasts have also been proposed for consonants at other manners of articulation in Lopit, and therefore an obvious direction for further research will be to investigate whether they exhibit duration differences of a similar sort (though the durational correlates of length contrasts are known to vary across manners of articulation). Selected spectrograms presented in Chapter 3 suggest that closure duration differences are likely for proposed geminates /tː, dː, nː, lː/ compared to singletons /t, d, n, l/, and that they may also exhibit the pre-geminate vowel shortening which was observed for Lopit glides, and which is a common finding in the phonetic literature on gemination. However, it remains to be seen whether the durational patterns corresponding to length distinctions across the consonant inventory are as robust as those for the glides, and indicative of a shared system. The functional load of some of these may also not be comparable to that of /wː/ and /jː/, and it is not yet clear whether the alveolar length contrasts, which are not observed in Eastern Nilotic languages outside the Lotuxo family (apart from the tap/trill distinction), originated in a similar way to the glide length contrasts. A more detailed understanding of consonant duration across Nilotic languages would offer further insight into the systematic uses of duration differences. For many Western Nilotic languages, and some Eastern Nilotic languages of the Bari group, long consonants are attested as the result of morphophonological processes, as well as sometimes having contrastive status (2.2.4), but in Lopit no evidence was found for productive gemination patterns at morpheme boundaries (3.3).

For Lopit, analyses of duration may be illuminating among the voiceless obstruents in general, recalling that, as noted in Chapter 3, some instances of voiceless stops /p/ and /k/ had noticeably long closures, though there was not evidence for contrastive length among these segments. There is an apparent relationship between these stops and the voiceless fricatives /f/ and /x/, with crosslinguistic data in sources such as Vossen (1982) suggesting that these Lopit fricatives were originally stops at some much earlier stage. If this is the case, the question, then, is why not all instances of the same voiceless stop became fricatives. It could be speculated that duration has some role to play in the stop/fricative relationship. Perhaps Lopit had two voiceless stop series, one singleton and one geminate, and the singleton series lenited to fricatives, or perhaps, for stops in a single voiceless series, positional or other effects (e.g. the salience of the stem-initial consonant slot among verbs, and associated possible correlates of domain-initial strengthening) prevented some stops from leniting to fricatives while others did. The variation between /c/ and /s/ observed by Stirtz (2014b) across Lopit dialects is further suggestive of a relationship between stops and fricatives. It is also worth noting that while Lopit contrasts /tː/ and /t/, data from Coates (1985), briefly discussed in 2.2.4, indicate that these correspond to /t/ and /θ/ in closely-related Otuho, giving rise to a more balanced set of voiceless stops and corresponding voiceless fricatives in that language. The relationship between stops and fricatives, and the possible role of duration in this, is a topic worth close examination for the languages of the immediate Lotuxo group.

It was observed that the length contrasts for glides, and for other segments in Lopit, are found word-initially as well as word-medially. As described in Chapter 3, word-initial occurrences of geminates are most often found in infinitive verb forms, which can appear in specific types of constructions, though the frequency with which these occur in natural speech is not known, and would benefit from the types of corpus studies suggested in 7.2. While phonetic investigations of word-initial glide realisations would require careful experimental design, and benefit from ongoing analyses of Lopit morphosyntax, the findings would have much to offer. Word-initial contrasts in consonant length are less common in the world's languages, and less well-understood. For glides, there are hints in example tokens from Itunyoso Trique that duration differences between singletons and geminates may be larger word-initially than word-medially (Maddieson, 2008). This has been a finding for singleton compared to geminate stops in other work, e.g. on Tashlhiyt Berber (Ridouane, 2007). Other cues may also enhance length contrasts in initial positions, particularly for voiceless stops for which segment duration may be difficult to perceive when word-initial (Ridouane, 2007; Hamzah, 2013), but patterns may differ for sonorants. More generally, the investigation of Lopit glides in different prosodic contexts would help to understand how the length contrasts are maintained, or adjusted, in different environments. Results presented in Billington (2016) indicate that the durations of geminate, but not singleton glides are affected by their occurrence in 2-syllable compared to 3-syllable words. A targeted investigation of glide duration in different word positions and word length would likely offer valuable insights.

Though the duration differences between Lopit singleton and geminate glides are clear, they are not the only phonetic differences. Each pair also shows significant differences in F1, of an estimated 135–160 Hz, and in F2, of 120–190 Hz. There are also F3 differences between /jː/ and /j/, and both pairs show differences of 3–4 dB in overall amplitude, either taken at the glide midpoint, or at the glide midpoint relative to the midpoint of the following vowel. These formant and amplitude differences point towards a more constricted articulation for geminate glides, and suggest the articulatory gesture for geminate glides involves a more raised tongue body and concomitant damping of the signal. Though no evidence was found for Turner's (2001) impressions that geminate /wː/ and /jː/ were produced with frication compared to /w/ and /j/, in addition to being longer, frication would be similarly indicative of a more constricted gesture and may be more characteristic of particular dialects, speakers or speech styles. While the articulation of Lopit glides has not been directly addressed in this project, the production of Lopit glides clearly lends itself to a study of the lingual gestures involved, for example using ultrasound or electromagnetic articulography. This would be extremely worthwhile to pursue, not only to gain a better understanding of the articulatory gestures distinguishing long and short glides, but also the timing with which these are implemented, given that the formant trajectories shown in Chapter 5 indicate that the geminate glides show more abrupt transitions to and from neighbouring vowels.

A point of particular interest would be whether similar strategies are used to distinguish geminate and singleton glides as are used to distinguish [+ATR] and [-ATR] vowels. As shown in Appendix D, mean F1 values for [+ATR] /i/ and [+ATR] /u/ are 283 Hz and 294 Hz respectively, compared to 362 Hz and 367 Hz for /ɪ/ and /ʊ/. For the glides, geminates /jː/ and /wː/ have mean F1 values of 276 Hz and 305 Hz, similar to those of the [+ATR] vowels, but singletons /j/ and /w/ have F1 values of 441 Hz and 436 Hz, somewhat higher than for the [-ATR] vowels. This is indicative of a more open quality for the singleton glides than for the [-ATR] close vowels, more similar to means for [+ATR] /e/ and /o/. As suggested in Chapter 5, the singleton glides may be more susceptible to the coarticulatory effects of neighbouring non-close vowels in the dataset. The realisation of Lopit glides in different vowel contexts, including between close vowels (a context not included in these data), is well worth examining, particularly given that both /j/ and /jː/ are often found following close front vowels when they are the first consonant of a Class 2 verb stem (the close vowel being the marker of verb class). The acoustic results for Lopit glides also give credence to the remarks of a more "close" or "more approximated" articulation compared to an "open" or "less approximated articulation" for the long/strong/fortis compared to short/weak/lenis glides attested elsewhere in Eastern Nilotic, for example among Maa varieties (see 5.2.8). They also raise questions about the nature of glide articulation across Eastern Nilotic languages, especially given that the geminate glides may have a common origin, but also given that they have been described with varying terminology. It is certainly possible that, despite a common origin, the reflexes in different Eastern Nilotic languages may vary. For example, /wː/ is suggested to derive from original stop-glide sequences (Vossen, 1982, pp. 249–252; Dimmendaal, 1983b, p. 14), and a change from a sequence of two segments to a single long segment is a common process in the emergence of geminates (Blevins, 2004). However, given that the sequence involves both a stop and a glide, it would also not be surprising if some aspects of a more consonantal articulation were also preserved, as the lower amplitude values suggest. Phonetic studies of glides in other Eastern Nilotic languages are clearly needed before the picture becomes clear.

However, given suggestions that for length contrasts among glides, duration differences may be difficult to perceive due to the spectral continuity with neighbouring vowels (Kawahara, 2007), perhaps it is the case that additional cues are required in order to maximise perceptual salience. Sophisticated perception studies will need to be devised to test this, and will depend first obtaining better knowledge of glide production across Eastern Nilotic languages, and in other languages. While some forays into the perception of glide length have been undertaken (e.g. Hansen, 2012; Hansen & Myers, 2017; Kawahara, 2007; Kawahara & Pangilinan, 2017), none have yet taken additional acoustic cues of this sort into account, though there is a more general finding that larger amplitude drops facilitate the identification of 'geminate' segment boundaries in synthesised speech (Kawahara & Pangilinan, 2017). The anecdotal observations of vowel quality differences in the environment of long/strong glides in Eastern Nilotic also warrant further investigation, such as suggestions from Coates (1985) that the geminate or 'strong' glides in Otuho tend to occur in the environment of [+ATR] vowels. While the phonological patterns discussed in 3.4.3.3 for Lopit demonstrate that the geminate glides can occur between either [+ATR] or [-ATR] vowels, it was also noted that vowels immediately preceding a geminate glide tend to have a closer quality. In preliminary acoustic observations for /a/ preceding Lopit geminate and singleton glides (recalling that acoustic and articulatory evidence established that /a/ does not have a [+ATR] counterpart), results for F1 and F2 at vowel midpoints suggest that the greater constriction for geminate glides is anticipated. These spectral cues would likely offer additional perceptual information, but the non-durational vowel correlates of consonant length contrasts (and any associated articulatory differences) have received very little attention in production and perception studies.

7.5 Tone Categories and Realisations

In Chapter 6, the phonetic realisation of tonal contrasts in Lopit was explored. In Chapter 3, a contrast between High, Low and Falling tones was proposed, with the syllable as the tone-bearing unit. As explained in 3.5, these proposed tonal distinctions are used, to some extent, in forming lexical contrasts. However, they also appear to be used for a number of grammatical functions, many of which are still under investigation. The focus of Chapter 6 was therefore nominal data, for which the grammatical uses of tone are better understood at this stage. The data are used to address RQ5 "What are the phonetic characteristics of lexically contrastive tones on nouns in Lopit?" Two hypotheses were developed for testing. For the first, the focus was on the phonetic evidence that the three tones are distinct. It was proposed that fundamental frequency, the major correlate of tone contrasts in the world's languages (6.2.4), would significantly differ for each of the three tones, and furthermore that differences in duration and overall amplitude may also be observed. This has sometimes been the case in other phonetic explorations of tone (6.2.4), and relates to some comments made by previous authors on Lopit and related languages (Turner, 2001; Baltazani, 2002). Other impressions of previous authors (Vossen, 1982; Turner, 2001) also raise the possibility of tone realisation varying depending on the identity of adjacent tones, and it was suggested that this needed to be also be examined as part of clearly establishing the tonal distinctions in Lopit. This was the focus of the second hypothesis.

Based on 1,362 tokens of High, Low and Falling tones in different tonal contexts in disyllabic words, collected with three participants, clear evidence was found that fundamental frequency is a robust correlate of tone category in Lopit. Significant differences were found in the f0 patterns for each tone occurring in the same tonal context (preceding or following a Low tone), taken at 25%, 50% and 75% of the way into the sonorant portion of the syllable rhyme. The High and Low tones, which were described as level tones, are differentiated by relatively high compared to low f0 values, with estimated differences of 17–34 Hz. The Falling tone, which was described as a contour tone, is characterised by high f0 values early in the syllable, similar to those of the High tone and an estimated 15–17 Hz higher than for the Low tone, before transitioning to lower f0 values later in the syllable, similar to those of the Low tone and an estimated 20–32 Hz lower than for the High tone. With reference to individual speaker ranges, the differences between tone categories ranged from 2–5 semitones. The finding of f0 as a correlate of Lopit tone is not surprising, given that it is the primary acoustic correlate of tone categories crosslinguistically, corresponding to percepts of pitch differences. However, it is the first phonetic evidence supporting phonological observations for tone contrasts in Lopit. For Nilotic languages, the phonetic understanding of tone realisation is mostly informed by data for Western Nilotic languages of the Dinka-Nuer branch (Remijsen, 2013; Remijsen & Ayoker, 2014; Gjersøe, 2016), which are quite different to Eastern Nilotic languages both in terms of word and syllable structure, as well as segmental and tonal inventories. Phonetic explorations of Eastern Nilotic tone appear to be limited to a study of interactions between tone, case-marking, and intonation in Maa (Baltazani, 2002).

Other possible correlates of tone category were also investigated, with mixed results. When the tones occurred as the second syllable of the disyllabic words, there was a trend of higher RMS amplitude values correlated with higher f0 values, with the estimated differences across the various comparisons being around 3 dB. Correlations of this sort have occasionally been found in other analyses of tone production (e.g. Zee, 1978; Whalen & Xu, 1992; Fu & Zeng, 2000), though acoustic measures beyond f0 are only infrequently included. RMS amplitude differences were not significant in initial syllables, but this is not particularly surprising given that the word-initial syllables were also utterance-initial in this citation form data. Baltazani (2002) has suggested that in Eastern Nilotic Maa, amplitude characteristics may provide cues to case-marking tones where the f0 characteristics of these are obscured by other intonation processes, though this has not been subject to perceptual research. For Lopit, further work will be required to determine whether these amplitude differences have salience for speakers. Some interesting tendencies were also observed for duration, such as higher duration values for Falling tones, a possibility previously mentioned by Turner (2001) for Lopit, and a common association for contour tones crosslinguistically (Gordon, 2001; Zhang, 2001). However, these tendencies were not significant, and closer inspection of the data suggested that duration results were likely particularly affected by the unbalanced distribution of tokens for different tones, and would particularly benefit from more nuanced investigations controlling for other segmental factors as further work on Lopit makes this possible (something which would, of course, also allow for more nuanced investigations of f0 patterns). The combined results for f0, duration and intensity for tones in different tonal environments in disyllabic words also suggest the possibility of higher-level prosodic patterns which result in greater prominence being given to some syllables, particularly those with High or Falling tones, in specific contexts.

In the associated comparisons of contextual variants of tones, however, duration differences emerged as an area of particular interest. It was found that the duration of Low tones is adjusted depending on which tones occur in adjacent syllables; if the preceding or following syllable is a Falling tone, a Low tone will be an estimated 47 ms shorter than if it were preceded or followed by another Low tone, and if the preceding or following tone is a High tone, a Low tone will be 35–41 ms shorter than if it were preceded or followed by another Low tone. High tones following a Low tone are also an estimated 30 ms longer than High tones following another High tone. These results suggest that High and

Falling tones are permitted to take up more durational real estate in the word, but that the tone-bearing unit is not solely responsible for producing this pattern; the duration of the adjacent syllable is adjusted to allow for it. This is an interesting finding, and not unlike segmental interactions reported in the literature, such as the widely observed adjacency effects for vowels preceding geminate consonants (5.2.5). Results of this sort presented for Lopit in Chapter 5 open the possibilities for future investigations of how specific segmental factors interact with tone realisation in the language. For example, investigations of tone timing, and specifically the timing of the f0 fall for the Falling tone, would be well served by experimental datasets including singleton and geminate consonants as onsets, to see how segmental timing differences influence tone realisation. Singleton and geminate glide onsets will be particularly well-suited to this, as their sonorant nature will permit f0 patterns to be observed across both the onset and the rhyme.

Other contextual effects were also found; High tones exhibit higher f0 values when they precede or follow Low tones compared to when they precede or follow other High tones, and Low tones following a High also have lower f0 values than Low tones following another Low (as well as lower RMS amplitude values). These results are indicative of tonal dissimilation, and suggest that High and Low tones are maximally distinct in a disyllabic word with a H.L pattern. If High and Low tones are most different when they neighbour syllables with different tones, this also raises the question of whether the tones are reliably distinct in words with H.H and L.L patterns. F0 results indicate they are, but the magnitude of the difference may be smaller. While investigations of tone realisation in words of different lengths will further develop the understanding of these patterns, these results fit with Turner's (2001) impressions that High tones may be higher in some contexts. Furthermore, the varied realisation of High tones may have contributed to Vossen's earlier impressions of a Mid tone for Lopit (Vossen, 1982). Mid tones have also been noted in early work on various other Nilotic languages (Tucker & Bryan, 1966), but have not tended to appear in more comprehensive analyses, and these findings suggest that inspection of the acoustic patterns may help to establish meaningful differences early on in investigations.

There is the potential for ongoing acoustic analyses to also offer insights into patterns of grammatical tone in Lopit. For example, it is interesting to recall that, as noted in 3.5.2, the grammatically marked nominative case is indicated by changes in the tone pattern across the noun which are to some extent lexically specified, but also frequently involve an initial High tone followed by a Low tone which, based on the results discussed here, may be afforded particular prominence. There may be a relationship between perceptual salience and grammatical markedness. More generally, it has been noted in the preceding two sections that further experimental work will benefit from the ongoing analyses of Lopit morphosyntax, and this is especially true for investigations of Lopit tone. Once grammatical tone changes on verbs are well-understood, verbal data will be excellently suited to phonetic investigations, as they will offer many possibilities to compare prosodic phenomena for lexical items which have different tones but the same segmental content. Given that the functional load of tone appears to be greater grammatically than lexically, it is also possible that tone categories may be more distinct when tested with verbal data (though they are clearly distinct on the basis of f0 in the current nominal data.) As investigations of Lopit tone progress, it will also be necessary to incorporate analyses of intonation patterns and how these interact with lexical and grammatical tone, a topic which is in general much-neglected in studies of African languages (though see e.g. Downing & Rialland, 2016).

This work demonstrates that despite the challenges associated with analyses of Nilotic tone, it is still possible for phonetic investigations of tone to take place in the early stages of language documentation. More generally, close attention to tone in the course of the wider Lopit language project has inspired greater confidence in analyses made at other levels of the linguistic system in concurrent work (e.g. Moodie & Billington, 2015). These findings also illustrate the value of including measures beyond f0 in phonetic studies of tone, and in considering acoustic and durational patterns across the word. Given that many African languages have quite different structures to the languages of East and South East Asia which have contributed most significantly to understandings of the phonetic correlates of tone, this may be an area in which further instrumental work on African languages will offer valuable typological insights. For Lopit, further work teasing apart the role of possible additional cues and how these, and f0, might vary depending on consonantal context, syllable type and vowel quality will benefit from greater availability of lexical data from which materials for both production and perception experiments can be compiled. As for all the quantitative results presented in this project, observations made in these first phonetic analyses for Lopit will also be strengthened by later work exploring segmental and tonal production across larger groups of speakers, and for speakers of different Lopit dialects.

7.6 Concluding Remarks

This thesis has provided a detailed description of Lopit phonology, accompanied by phonetic evidence for a 9-vowel monophthong inventory with an 'Advanced Tongue Root' contrast, a length distinction among glides at the same place of articulation, and three contrastive tones. Importantly, the phonetic and phonological analyses point towards a shared system for speakers of the Dorik dialect of Lopit who have contributed most substantially to this study. As well as contributing to the description of Lopit, these findings provide quantitative evidence that language documentation and phonetic experimentation undertaken with diaspora communities make a valuable contribution to understanding the linguistic patterns of a language. It is hoped that this work will be followed by more detailed and extensive analyses of Lopit phonetics and phonology, and that the near future will see an improved sociopolitical situation in South Sudan which also permits such work to take place with communities in the Lopit Mountains, and with speakers of other related languages. The linguistic record for many languages of this region is extremely limited, but the results of this project together with available data for related languages show that Nilotic languages have much to offer in terms of developing crosslinguistic understandings of segmental and tonal patterns, and will benefit the understanding of linguistic and areal relationships. More generally, it is hoped that this work will be part of an increased focus on the phonetic characteristics of African sound systems and the various insights they have to offer.

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Appendix A

Abbreviations and Glosses

1	first person
2	second person
3	third person
ATR	Advanced Tongue Root
C	consonant
CQ	Contact Quotient
dB	decibels
EGG	electroglottography
F	feminine grammatical gender
F	Falling tone
$f0$	fundamental frequency
F_1	first formant frequency
F_2	second formant frequency
F_3	third formant frequency
G	glide
H	High tone
Hz	Hertz
IMP	imperative
INF	infinitive
IPFV	imperfective
L	Low tone
M	masculine grammatical gender
mm	millimetres
MRI	Magnetic Resonance Imaging
ms	milliseconds
NOM	nominative
PL	plural
PF	perfective
REDUP	reduplicated
RMS	root mean square
RQ	research question
RTR	Retracted Tongue Root
SG	singular
sp.	species
UTI	Ultrasound Tongue Imaging
V	vowel
VEN	ventive
VSO	Verb-Subject-Object

Appendix B
Phonology Data References

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Appendix C
Wordlists

C.1 Swadesh list for Dorik Lopit

Table C.1: *Swadesh list (207 items) for Dorik Lopit, as an example of data collected in the earliest stages of this project. The items on this list are a modified version of materials presented in Swadesh (1952) and Swadesh (1955), following recent examples such as Olson et al. (2009). The Lopit forms are shown here in broad phonetic transcription; a close phonetic version of this list was discussed at a talk towards the beginning of this project (Billington et al., 2011).*

Item	English gloss	IPA	Comment
1	I	nàŋ	-
2	you (singular)	ìjè	-
3	he	ìɲɛ̀	'he, she'
4	we	ìjòxoí	-
5	you (plural)	ìtɛì	-
6	they	ìcè	-
7	this	ín:á	feminine
	this	íl:ɛ́	masculine
8	that	njà	feminine
	that	ljà	masculine
9	here	ín:í	-
10	there	dâ	-
11	who	ŋaì	-
12	what	ɲó	-
13	where	àɟì	-
14	when	ànù	-
15	how	ɟeì	-
16	not	íɲà	-

Continued on next page

Table C.1 – *continued from previous page*

17	all	fúr	-
18	many	ɔ́lːʊ́ŋà	-
19	some	xùrêʔ	feminine, also 'other'
	some	xʊ̀lák	masculine, also 'other'
20	few	ɔ́mʊ́tà	'small'
21	other	xùrêʔ	feminine , also 'some'
	other	xʊ̀lák	masculine, also 'some'
22	one	nàboîtoî	feminine
	one	lòboîtoî	masculine
23	two	lɔ̀xɔ́rìk	-
24	three	lòxúnìk	-
25	four	lɔ̀ŋwân	-
26	five	mjɛ̀t	-
27	big	ɔ̀bɔ̀rɔ̀	also 'to be important; more senior'
28	long	ɛ̀ságà	also 'tall'
29	wide	ɛ̀lát	-
30	thick	ófótì	-
31	heavy	ɛìdʊ̀râ	-
32	small	ɔ́mʊ́tà	-
33	short	òsúk	-
34	narrow	ɛ̀mìrìxídáʔ	-
35	thin	énjémà	-
36	woman	nàŋòrúò	also 'wife'
37	man (adult male)	xòdótìtî	-
38	man (human being)	tɔ̀xɔ̀nî	-
39	child	xìtó	-
40	wife	nàŋòrúò	also 'woman'
41	husband	lɔ̀rɛ̀wâ	-
42	mother	xɔ̀tːɔ̀ɲì	-
	mother	íjáŋ	vocative, addressing female elders.
43	father	mɔ́ɲɛ́	-
	father	ábá	vocative, addressing male elders
44	animal	tjàŋ	-
45	fish	xàmî	-
46	bird	cèŋî	-

Continued on next page

Table C.1 – *continued from previous page*

47	dog	xíŋɔ̀xɔ̂	-
48	louse	làkjétí	-
49	snake	múnú	-
50	worm	xùrútì	any small invertebrate
51	tree	jànì	same as 'fruit'
52	forest	tʊ́tʊ̀r	-
53	stick	xìrì	'walking stick for women'
	stick	cɔ́l	'stick for fighting'
54	fruit	jànì	same as 'tree'
55	seed	xìɲómòtî	-
56	leaf	fàraí	-
57	root	xàdːétí	-
58	bark (of a tree)	xɔ́bɔ́xɔ́bɔì	-
59	flower	tʊ́rɛ́ná	-
60	grass	tìm	'bushland, scrub'
	grass	xúɟútí	'grass for thatching houses'
61	rope	xòfítè	-
62	skin	múxúɲó	of animal or human
63	meat	xìríŋò	-
64	blood	xɔ́tɔ́	-
65	bone	xòítè	-
66	fat (noun)	sʊ̀mɛî	-
67	egg	xàtːélí	-
68	horn	mwáráxì	-
69	tail	xìdɔ̀ŋɛ̂	long, thin tail, e.g. as of a giraffe
70	feather	xòfitːî	also 'hair' (singular)
71	hair	xòfir	-
72	head	xɔ̀ʔ	-
73	ear	xìjɔ̀k	-
74	eye	xɔ̀ɲɛ̀k	-
75	nose	xìmô	-
76	mouth	xʊ́tʊ́k	-
77	tooth	xàlátì	-
78	tongue	ŋádjéf	-
79	fingernail	xàbúxèlí nà xáná	lit. 'nail of hand'

Continued on next page

Table C.1 – *continued from previous page*

80	foot	xɛ̀ɟʊ̀ íɾjét	lit. 'base of leg'
81	leg	xɛ̀ɟʊ̀	-
82	knee	xʊ́ŋʊ́	-
83	hand	xáná	also 'arm'
84	wing	ìwːaî	-
85	belly	xɔ́sɛ̀xɛ̀	-
86	guts	xòtwâʔ	also 'inside(s)' more generally
87	neck	mʊ́ɾʊ́t	-
88	back	xʊ́ɾwɔ̀ŋ	-
89	breast	xìnɛî	-
	breast	sʊ́gɛ́	'chest'
90	heart	tàɲì	-
91	liver	mʊ̀ɲà	-
92	to drink	màtà	-
93	to eat	dàxà	-
94	to bite	xɔ̀ɲà	'to bite meat; to consume'
95	to suck	jʊ̀rà	-
96	to spit	mítá	-
97	to vomit	ceìtáʔ	-
98	to blow	xʊ̀tà	-
99	to breathe	xìjéxítà	-
100	to laugh	cènìtà	-
101	to see	wòlò	-
102	to hear	xìtáníŋóʔ	-
103	to know	xíjén	-
104	to think	xìtítíjóʔ	-
105	to smell	xìŋwàdà	-
106	to fear	bàŋî	-
107	to sleep	ɟètò	-
108	to live	wːàràn	' to be alive'
109	to die	jɛî	-
110	to kill	tːɔ̀xɔ̀	-
111	to fight	xìɾìbò	-
112	to hunt	lìxà	-
113	to hit	bàxà	-

Continued on next page

Table C.1 – *continued from previous page*

114	to cut	ŋɔ̀tɔ̀	-
115	to split	xɔ̀rà	-
116	to stab	cùxò	-
117	to scratch	xɔ́ɟɔ̀	-
118	to dig	bɔ́xá	'to dig with hands'
119	to swim	xìkwàŋà	-
120	to fly	xíwːárítà	-
121	to walk	lɔ̀tɔ̀n	-
122	to come	ŋàjɔ̂ŋ	-
123	to lie (as in a bed)	ŋàférjè	-
124	to sit	ŋàwʊ́ɲɛ̀	-
125	to stand	woìtà	-
126	to turn (intransitive)	fɛ̀là	-
127	to fall	bʊ́lːʊ́ŋ	-
128	to give	xìsò	-
129	to hold	xínɛ́fítà	-
130	to squeeze	mótá	-
131	to rub	xìfúfúsòʔ	same as 'wipe'
132	to wash	xìlːáʔ	-
133	to wipe	xìfúfúsòʔ	same as 'rub'
134	to pull	nító	-
135	to push	ɟʊ̀là	-
136	to throw	xìbírò	-
137	to tie	xífítà	-
138	to sew	rìfà	-
139	to count	xìxɛ̀nà	also 'to read'
140	to say	xìɟò	also 'because'
141	to sing	xìdòlò	-
142	to play	xírámítà	-
143	to float	ɛ́ŋér tɛ̀ xídɛ́ nà xìfjôŋ	lit. 'to be on the surface of the water'
144	to flow	ŋɛìtːà	of water, e.g. a river
145	to freeze	xìtílíxáʔ	'to make cold'
146	to swell	ŋàjɛ́ɟàk	-
147	sun	xɔ̀lɔ̀ŋ	also 'day'
148	moon	áfàʔ	also 'month'

Continued on next page

Table C.1 – *continued from previous page*

149	star	áxéɾí	-
150	water	xìfjôŋ	-
151	rain	xaíʔ	-
152	river	xáɾí	-
	river	wɔ́r	‘riverbed, with or without water; valley’
153	lake	táfár	small body of water during rainy season
154	sea	xáɾí nà tɔ̀gɔ́l	lit. ‘river of boats’
155	salt	bàlàŋ	also ‘broth, soup’
156	stone	móɾwó	-
157	sand	sìŋjátí	-
158	dust	fʊ́r	-
159	earth	xɔ̀f	-
160	cloud	dìdíxòʔ	-
161	fog	lɔ̀rìɲàʔ	-
162	sky	ídóʔ	-
163	wind	lɔ̀jːàmî	-
164	snow	tɛ́ɾɛ́ʔ nà xìtːɔ̂k	not found in the Lopit area; lit. ‘big hail’
165	ice	tɛ́ɾɛ́ʔ	‘hail’
166	smoke	fúɾjó	-
167	fire	xìmà	-
168	ash	xìnwàɾà	-
169	to burn	xìdjá	-
170	road	ìxɔì	-
171	mountain	dɔ́ŋɛ́	also ‘village’, ‘Lopit people’
172	red	ɔ̀dɔ́	-
173	green	ɔ́ɲɔ́ɾì	-
174	yellow	lɔ̀ɟɛ̀k	name of a yellow-coloured weaver bird sp.
175	white	òbwór	-
176	black	èɾjók	also ‘dark’ (no light)
177	night	táɾíʔ	early evening; dark but before people go to sleep
178	day	fár	‘daytime’, as opposed to night
	day	xɔ̀lɔ̀ŋ	relating to time, also ‘sun’
179	year	xíŋá	also ‘hunger, famine’
180	warm	eìlûʔ	of things, also ‘hot’
	warm	ɔ̀nɔ́k	of weather, also ‘hot’

Continued on next page

Table C.1 – *continued from previous page*

181	cold	ɛìlík	of things, e.g. water
	cold	xìrɔ́bì	of weather
182	full	ɛífʊ̀t	as of a container
183	new	ŋéɟúk	-
184	old	ɛ̀márwàk	-
185	good	ɛ́líbà	-
186	bad	òrúʔ	-
187	rotten	ɔ́mʊ́rà	-
188	dirty	ɛìbɔ́t	-
189	straight	ɔ̀bʊ́s	-
190	round	ɔ́rʊ́ŋà	-
191	sharp (as a knife)	ɛ̀fíʔ	-
192	dull (as a knife)	ótútúɲò	'blunt'
193	smooth	ɛ̀ɲíl	-
194	wet	òfúʔ	-
195	dry	ót:oí	-
196	correct	ɛ́tɛ́n	-
197	near	èrék	-
198	far	ɔ́lɔ́mà	-
199	right	íxɔ́tɔ́ɲ	-
200	left	íxádjén	-
201	at	dɛ̂	also 'on', 'in'
202	in	dɛ̂	also 'on', 'at'
203	with	xɔ̀	same as 'and'
204	and	xɔ̀	same as 'with'
205	if	lɔ́	particle before verb
206	because	xìɟò	also 'to say'
207	name	fʊ́ré	also 'song'

C.2 Wordlists for vowel analyses, Chapter 4

Table C.2: *Wordlist for acoustic study of [+ATR] and [-ATR] monophthongs. Segments in bold indicate those used in analyses, and * indicates the subset of high-toned vowels used for analyses of spectral emphasis.*

[+ATR]		[-ATR]	
[i]		[ɪ]	
ídóʔ	sky SG	**ɪ́**gʊ́ʔ	corner SG
x**ì**tó	child SG	x**ɪ̀**tɔ̂	scorpion SG
x**ì**tːò	bottom SG	x**ɪ́**tʊ́	bad luck charm SG
x**í**tːós	bottoms PL *	x**ɪ́**tɛ́ŋ	cow SG *
xáɾ**í**	rod, switch SG	xáɾ**ɪ́**	river SG
x**ì**ɾì	women's walking stick SG	x**ɪ́**ɾí	waterhole SG *
íx**í**tá	carrying ring SG *	x**ɪ̀**tàʔ	piece of wood SG
xóf**í**ɾí	hair, feather SG *	xɪ̀f**ɪ́**ɾɛ̀	stirring tool SG[1] *
xòf**í**tè	rope SG *	x**ɪ́**tábɔ́k	small animal trap SG *
íxítá	carrying ring SG	**ɪ́**xɛ́ɾɛ́k	turtle SG
[e]		[ɛ]	
áx**é**ɾí	star SG *	ɪ́x**ɛ́**ɾɛ́k	turtle SG *
lòs**é**ɾì	corn SG[2] *	xɔ́s**ɛ̀**xɛ̀	stomach SG
tùx**ê**sô	raven sp. PL	lɔ̀f**ɛ́**ɾʊ̀ʔ	ticks PL *
xòfít**è**	rope SG	t**ɛ̀**bɛ̀làʔ	earlobes PL
bíl**é**tí	wire SG	mɛ̀t**ɛ̀**ɾɛ̀	grass effigy SG
tìx**é**tí	manes PL *	xɔ́s**ɛ́**xɛ́n	stomachs PL *
tùx**ê**	raven sp. SG	k**ɛ̀**bʊ̀	hoe SG
xàdː**é**tí	tree root SG	lɔ̀tː**ɛ́**xíʔ	mousetraps PL *
xàtː**é**lí	egg SG *	tɛ̀b**ɛ̀**làʔ	earlobes PL
lófíɾ**é**ʔ	fishing spear SG	mɛ̀tɛ̀ɾ**ɛ̀**	grass effigy SG
[o]		[ɔ]	
x**ò**sî	heads PL	s**ɔ̀**xɔ̂t	coconuts PL
t**ó**síʔ	scorpions PL *	x**ɔ́**tɔ́	blood SG *
x**ó**ɾòsìʔ	debts PL	x**ɔ́**sɛ̀xɛ̀	stomach SG

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[1]This noun is produced with /b/ rather than /f/ by one speaker, and is usually produced with a final monophthong, but may also be produced with the diphthong [ɛɪ], which appears to be part of the stem (as seen in plural form /fiɾɛìʔ/).

[2]As noted in 3.3, this noun is one of few examples where speakers show variation in the consonants produced (with some using /c/ rather than /s/).

Table C.2 – *continued from previous page*

f**ó**tír	warthog SG *	f**ɔ́**fɔ́ŋ	cactus trees PL *
t**ó**rú	axe SG *	t**ɔ́**bɔ́k	clay bowl SG *
k**ò**rì	giraffe SG	x**ɔ̀**rɔ̀s	debt SG
sòx**ó**tí	coconut SG *	xɔ̀x**ɔ́**rɔ́n	chickens PL *
s**ò**xínè	thing SG	s**ɔ́**xɔ́rɔ́	dancing bell SG
xòd**ó**tì	man SG	íd**ɔ́**lɔ́ʔ	locust SG
xìt**ó**	child SG	xìt**ɔ̂**	scorpion SG
	[u]		[ʊ]
ìx**ù**lóʔ	calabash SG	íg**ʊ́**rá	flood SG
b**ú**ríʔ	open areas PL	b**ʊ̀**xù	shield SG
lòg**ú**ríʔ	granaries PL *	ìg**ʊ́**xá	corners PL *
g**ú**mì ʔ	plains PL[3]	íg**ʊ́**ʔ	corner SG
x**ú**rú	worms, small invertebrates PL *	t**ʊ́**tʊ̀r	forest SG *
k**ú**dòk	round calabash SG *	x**ʊ́**tʊ́k	mouth SG *
t**ù**xê	raven sp. SG	xʊ́t**ʊ́**k	mouth SG
xùt**ú**xén	mouths PL	lɔ̀x**ʊ́**rʊ̀k	raven sp. SG
t**ù**túrí	forests PL	s**ʊ̀**gɛ̀nàʔ	chests PL
tùt**ú**rí	forests PL *	t**ʊ́**rɛ́ná	flower SG *
	[a] in [+ATR] context		[a] in [-ATR] context
g**à**rì	animal track SG	**à**xɛ̀r	stars PL
t**à**rùxê	vulture SG[4]	ìr**à**sî	brother SG
áxérí	star SG	xít**á**bɔ́k	small animal trap SG *
íxít**á**	carrying ring SG	xìt**à**ʔ	piece of wood SG
x**á**rí	rod, switch SG *	x**á**rí	river SG *
x**á**bó	antelope sp. SG *	x**á**bʊ́	rainmaker SG *
x**à**dːétí	tree root SG	tɔ̀bɔ̀x**à**	clay bowl SG
x**à**bùsìʔ	rainmakers PL	ìgʊ́x**á**	corners PL
x**à**látì	tooth SG *	x**à**tːɛ̀l	eggs PL
l**á**kːjéʔ	lice PL *	xɔ́xɔ́l**á**k	thieves PL *

[3] One participant uses the alternative plural form /gúmò/ instead.

[4] This noun is usually produced with a final monophthong, but may also be produced with the diphthong [ei] (see 3.4.3.4).

Table C.3: *Wordlist for articulatory study of [+ATR] and [-ATR] monophthongs. Segments in bold indicate those used in analyses.*

[+ATR]		[-ATR]	
[i]		[ɪ]	
x**ì**ɾì	women's walking stick SG	x**í**ɾí	waterhole SG
x**ì**tó	child SG	x**ì**tɔ̂	scorpion SG
[e]		[ɛ]	
áx**é**ɾí	star SG	íx**ɛ́**rɛ́k	turtle SG
xàtː**é**lí	egg SG	lɔ̀tː**ɛ́**xíʔ	mousetraps PL
[o]		[ɔ]	
t**ó**ɾú	axe SG	t**ɔ́**bɔ́k	clay bowl SG
f**ó**tír	warthog SG	f**ɔ́**fɔ́ŋ	cactus trees PL
[u]		[ʊ]	
x**ú**ɾú	worms, small invertebrates PL	x**ʊ́**tʊ́k	mouth SG
ìx**ù**lóʔ	calabash SG	lɔ̀x**ʊ́**rʊ̀k	raven sp. SG
[a] in [+ATR] context		[a] in [-ATR] context	
x**á**ɾí	rod, switch SG	x**á**ɾí	river SG

C.3 Wordlist for glide analyses, Chapter 5

Table C.4: *Wordlist for acoustic study of singleton and geminate intervocalic glides. Segments in bold indicate those used in analyses.*

Geminate		Singleton	
[wː]		[w]	
tɔ́**wː**ánàʔ	stay IMP	tɔ́**w**álàʔ	cough IMP
á**wː**ár	be alive 1SG	á**w**ák	want 1SG
à**wː**áŋàʔ	red monkeys PL	á**w**álà	cough 1SG
à**wː**ɔ̀ŋ	red monkey SG	á**w**óló	see 1SG
á**wː**ɔ́n	be at 1SG	á**w**oítà	stand 1SG
xà**wː**àʔ	arrows PL	á**w**à	submerge 1SG
xà**wː**eî	arrow SG[5]	ɔ́**w**à	submerge 3SG
lò**wː**âʔ	tree sp. PL	xɔ̀**w**àʔ	sweet potatoes PL[6]
lò**wː**eî	tree sp. SG	xò**w**eî	sweet potato SG
lé**wː**á	gazelle sp. SG	rɛ̀**w**à	husbands PL
ɔ̀**wː**ár	be alive 3SG	ɔ̀**w**áŋ	be bright 3SG
ɔ̀**wː**ɔ́n	be at 3SG	ɔ́**w**ák	want 3SG
ɔ̀**wː**ànaî	stay 3SG	ɔ́**w**álà	cough 3SG
tà**wː**ák	quickly	tɔ́**w**áxà	want IMP
lɔ̀**wː**àrìbák	spinach sp. SG	lɔ́**w**áxànàʔ	snake sp. SG
aílá**wː**áʔ	swing 1SG	lɔ̀**w**àxánáʔ	snake sp. PL
ɛìlà**wː**áʔ	swing 3SG	lɔ̀rɛ̀**w**â	husband SG
xɔ́sò**wː**àn	buffalo SG	tó**w**oítàʔ	stand IMP
ílá**wː**áʔ	swing 2SG	ó**w**óló	see 3SG
lè**wː**ànàʔ	gazelle sp. PL	ó**w**oítà	stand 3SG
lɛílá**wː**àrì	playground SG[7]	tó**w**ólò	see IMP
		tɔ́**w**à	submerge IMP
[jː]		[j]	
té**jː**ò	cry IMP	tɛ́**j**ó	die IMP
tɛ́**jː**ɛ̀t	pull IMP	tɛ́**j**ɛ̀f	chop IMP

Continued on next page

[5]For 'arrow SG', 'tree sp. SG' and 'sweet potato SG', and some other nouns with singulative suffix /-i/, the final diphthong may optionally be produced as a monophthong (see 3.4.3.4).
[6]Some speakers also use /xàwàʔ/ and /xàweî/ (SG) (both reportedly more common in other dialect areas).
[7]Only produced by one speaker.

Table C.4 – *continued from previous page*

á**j:**ɛ́tà	pull 1SG	á**j**ɛ́fà	chop 1SG[8]
á**j:**ò	cry 1SG	â**j**ɛî	die 1SG
á**j:**ánì	bring 1SG	á**j**étà	carry 1SG[9]
íxá**j:**á	pumpkin leaves PL	íxá**j**á	grass sp. PL
lɔ́sà**j:**èʔ	messenger SG	xíjà**j**àʔ	porcupine PL
lɔ̀sà**j:**éxíʔ	messengers PL	xíjà**j**áxíʔ	porcupines PL[10]
xá**j:**òk	mourners PL	xâ**j**ɔ̀k	dead people PL
xá**j:**ônì	mourner SG	xá**j**ônì	dead person SG
sà**j:**èʔ	message SG	á**j**áxà	pull out 1SG
sà**j:**éɟín	messages PL	màlà**j**ɔ̀ʔ	snake sp. SG
xà**j:**ɔ́xɔ̀k	herders PL	á**j**ɔ́xà	graze 1SG
é**j:**ò	cry 3SG	ɛ̀**j**ɛî	die 3SG
ɛ́**j:**ɛ́tà	pull 3SG	ɛ́**j**ɛ́fà	chop 3SG
ɛ̀**j:**ánìʔ	bring 3SG	ɛ́**j**étà	carry 3SG
xò**j:**âʔ	yams PL	ɛ̀**j**ɛ́ʔ	swell 1SG
xò**j:**aʊ̀ʔ	any wild food PL	kɛ́**j**àʔ	peanut sp. PL
xò**j:**átì	yam SG	kɛ̀**j**átí	peanut sp. SG
áxó**j:**à	forage 1SG	ɔ́**j**ɔ́xà	graze 3SG
xò**j:**èk	wood PL	tɛ́**j**ɛ̀ʔ	hold IMP
lɔ̀**j:**àmî	wind, air SG	tɛ́**j**áxù	pull out IMP VEN
íxó**j:**à	forage 2SG	ɛ́**j**áxà	pull out 3SG
eíxò**j:**à	forage 1PL	já**j**áʔ	porcupines PL

[8] For this verb, and the 3SG form below, some tokens were produced in the neutral non-imperfective form, which lacks the final vowel.

[9] For this verb, and the 3SG form below, the stem is optionally produced with a diphthong [ei] by some speakers, whereas for others it is always [e] (see 3.4.3.4).

[10] Two speakers use this plural form, and three use /jájáʔ/, below.

C.4 Wordlist for tone analyses, Chapter 6

Table C.5: *Wordlist for acoustic study of High, Falling and Low tones on disyllabic nouns. Segments in bold indicate syllables used in analyses.*

Tone pattern			
L.L		H.H	
gɔ̀nɛ̀	colleague SG	**bɔ́ŋɔ́**	piece of clothing SG
xàwːàʔ	arrows PL	**dɔ́ŋɛíʔ**	giraffe tails PL
xɔ̀lɔ̀ŋ	sun SG	**dɔ́ŋjɔ́k**	mountains PL[11]
xʊ̀ŋà	knees PL	**dʊ́rɛ́**	children PL[12]
ìɲɛ̀	3SG	**xáná**	hand, arm PL
rɛ̀ɲì	son SG[13]	**xíné**ʔ	goat SG
màrìŋ	fence SG	**xʊ́nóm**	cave SG
mɛ̀nɛ̀ŋ	prize kill SG	**lɛ́wːá**	gazelle sp. SG
rɛ̀wà	husbands PL	**límá**	sheep tail SG
ràŋà	bows PL	**lɔ́rɛ́**	flat rock for drying SG
jànì	tree SG	**máná**	farm SG
ìjè	2SG	**márwák**	animal horns PL
kòrì	giraffe SG	**mɔ́ɲɛ́**	father SG
mɔ̀lɔ̀ŋ	baboon SG	**jání**ʔ	trees PL
mɔ̀rìŋ	gazelle sp. SG		
àwːɔ̀ŋ	red monkey sp. SG		
xìnè	goats PL		
L.H		H.L	
lɔ̀rɛ́	yam sp. SG	**bɛ́rɛ̀t**	flag SG
bɛ̀lá	whistle SG	**bónːì**ʔ	antelope sp. SG[14]
fàraí	leaf SG	**gʊ́mɪ̀**ʔ	plains PL
xìtó	child SG	**xɔ́fɪ̀**ʔ	earth, lands PL
màríʔ	rib SG[15]	**kálɪ̀**ʔ	sides, edges PL

Continued on next page

[11] 'Mountains PL' is produced with [+ATR] vowels by one speaker.

[12] 'Children PL' has a variant form /wʊ́rɛ́/, reportedly used most often as a vocative.

[13] For 'son SG', one speaker prefers the form /lɛ̀ɲì/ (reportedly more common in other dialect areas).

[14] For 'antelope sp. SG', one participant used the alternative plural /bórìʔ/. For this word, as well as for 'valleys, riverbeds PL' and 'small holes PL', the plural suffix may optionally be produced as [-iʔ] or [-ɪʔ].

[15] Alternative number-marked forms (not produced as part of data collected for these analyses) for 'rib SG' and 'ribs PL' are /màrítí/ and /màríɟín/ respectively. The variation appears to depend on whether the singular or the plural is treated as the unmarked form, as also noted by Moodie (2016) for nouns denoting pairs.

Table C.5 – *continued from previous page*

sànaí	branch SG	**lɔ́mɛ̀ʔ**	millet PL
sànáʔ	branches PL	**máŋì**	mango SG
sɔ̀lɔ́ʔ	spoon, shell SG	**wɔ́nːìʔ**	valleys, riverbeds PL
		wːórìʔ	small holes PL[16]
		búrìʔ	open areas PL
		kɛ́jàʔ	peanut sp. PL
		tímɔ̀	grasslands PL[17]
L.F		F.L	
dòmjô	knives PL	**bɔ̂rɛ̀**	stable SG
fwàrâ	dancing area SG	**mârìʔ**	ribs PL
xàwːeî	arrow SG[18]	**mârwàk**	old people PL
xìmô	nose SG	**pɔ̂rɛ̀ʔ**	game type SG
xìnɛî	breast SG	**ŋɔ̂rɔ̀s**	butter SG
xìrɛ̂ŋ	hide clothing SG		
xɔ̀bɔ̂n	sack SG		
xòjːâʔ	yams PL		
ɟànjâ	brooms PL		
ɟànî	broom SG		
lɔ̀mɛî	distance SG		
màŋât	elders' area SG		
mɔ̀ŋâ	magic stones PL		
mɔ̀ɲɛî	fathers PL		
wɔ̀lɔ̂	pigeon sp. SG		
cɔ̀lâ	men's sticks PL		
cèŋî	bird SG		
xìfjôŋ	water PL		
xùrêʔ	some F		
xùrô	goat/sheep kids PL		
ìfû	monitor lizard sp. SG		
ìŋɛ̂	baby SG		
ìwːâʔ	wings PL		

[16] 'Small holes PL' also has the variant form /wːɔ́nːìʔ/ (as shown in 3.3.2).
[17] Only produced by one speaker.
[18] For 'arrow SG', 'breast SG', 'distance SG' and 'fathers PL', the final diphthong may optionally be produced as monophthongal [e] (see 3.4.3.4).

Appendix D

Descriptive Statistics

D.1 Descriptive statistics for vowel data, Chapter 4

Table D.1: *Summary of F1 results for Lopit monophthongs by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in Hz) at vowel midpoints.*

V	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
i	120	283	288	30	155	351
ɪ	120	362	367	42	222	465
e	120	432	434	41	348	561
ɛ	120	537	537	45	400	654
a	120	683	688	68	543	844
a+	120	670	671	70	530	826
ɔ	120	538	542	51	383	652
o	120	412	407	54	231	571
ʊ	120	367	365	46	278	478
u	120	294	293	27	213	363

Table D.2: *Summary of F2 results for Lopit monophthongs by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in Hz) at vowel midpoints.*

V	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
i	120	2200	2189	151	1787	2597
ɪ	120	2080	2083	103	1781	2276
e	120	1883	1896	104	1625	2140
ɛ	120	1770	1769	103	1424	1978
a	120	1392	1399	117	1146	1704
a+	120	1441	1451	102	1196	1685
ɔ	120	1107	1083	128	866	1480
o	120	1011	995	145	762	1530
ʊ	120	955	944	158	607	1413
u	120	915	892	179	564	1441

Table D.3: *Summary of F3 results for Lopit monophthongs by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in Hz) at vowel midpoints.*

V	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
i	120	2845	2861	212	2243	3259
ɪ	120	2762	2752	166	2312	3260
e	120	2680	2653	173	2234	3016
ɛ	120	2645	2655	178	2187	2966
a	120	2535	2516	163	2159	3100
a+	120	2587	2551	185	2280	3106
ɔ	120	2552	2481	220	2100	3075
o	120	2602	2574	191	2290	3021
ʊ	120	2563	2518	201	2224	2955
u	120	2532	2466	199	2212	3014

Table D.4: *Summary of Euclidean distance results for Lopit monophthongs by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in Hz) at vowel midpoints.*

V	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
i	120	746	735	149	354	1136
ɪ	120	614	614	101	343	805
e	120	411	423	104	150	666
ɛ	120	310	323	97	38	504
a	120	267	269	60	99	406
a+	120	239	246	67	94	377
ɔ	120	384	411	118	89	615
o	120	470	484	143	54	731
ʊ	120	531	544	154	113	885
u	120	589	605	164	148	930

Table D.5: *Summary of duration results for Lopit monophthongs by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in ms) at vowel midpoints.*

V	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
i	120	139	134	37	59	230
ɪ	120	136	132	34	56	241
e	120	156	153	36	85	276
ɛ	120	138	136	37	64	227
a	120	139	135	48	58	270
a+	120	141	125	58	53	288
ɔ	120	137	131	40	65	269
o	120	152	145	40	69	255
ʊ	120	131	124	41	55	229
u	120	151	148	47	60	251

Table D.6: *Summary of spectral emphasis results for Lopit monophthongs by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in dB) at vowel midpoints.*

V	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
i	48	3	3	2	0	7
ɪ	48	4	4	2	2	10
e	48	5	4	2	2	10
ɛ	48	6	6	2	2	13
a	48	7	6	3	1	12
a+	48	6	5	3	2	13
ɔ	48	6	6	2	3	10
o	48	5	5	3	1	11
ʊ	48	4	4	2	1	9
u	48	3	3	1	0	7

Table D.7: *Summary of the results of statistical comparisons of acoustic meaasures for all vowels. For readability, some comparisons are repeated twice. Separate comparisons are not shown for tokens of /a/ in the [+ATR] environment and /a/ in the [-ATR] environment, compared to other vowels, as results were identical (***=p<0.001, **=p<0.01, *=p<0.05, - = NS).*

Comparison	F_1	F_2	F_3	Euclidean dist.	Duration	Spectral emph.
/i/ ∼ /ɪ/	***	***	-	***	-	-
/i/ ∼ /e/	***	***	***	***	***	**
/i/ ∼ /ɛ/	***	***	***	***	***	***
/i/ ∼ /a/	***	***	***	***	***	***
/i/ ∼ /ɔ/	***	***	***	***	***	***
/i/ ∼ /o/	***	***	***	***	*	**
/i/ ∼ /ʊ/	***	***	***	***	**	-
/i/ ∼ /u/	-	***	***	***	***	-
/ɪ/ ∼ /i/	***	***	-	***	-	-
/ɪ/ ∼ /e/	***	**	-	***	***	-
/ɪ/ ∼ /ɛ/	***	***	***	***	***	-
/ɪ/ ∼ /a/	***	***	***	***	**	-
/ɪ/ ∼ /ɔ/	***	***	***	***	-	-
/ɪ/ ∼ /o/	***	***	***	***	-	-
/ɪ/ ∼ /ʊ/	-	***	***	-	***	-
/ɪ/ ∼ /u/	***	***	***	-	**	*
/e/ ∼ /i/	***	***	***	***	***	**
/e/ ∼ /ɪ/	***	**	-	***	***	-
/e/ ∼ /ɛ/	***	***	**	***	-	-
/e/ ∼ /a/	***	***	***	***	*	-
/e/ ∼ /ɔ/	***	***	***	***	***	-
/e/ ∼ /o/	-	***	***	-	***	-
/e/ ∼ /ʊ/	**	***	***	-	**	-
/e/ ∼ /u/	***	***	***	***	-	**
/ɛ/ ∼ /i/	***	***	***	***	***	***
/ɛ/ ∼ /ɪ/	***	***	***	***	***	-
/ɛ/ ∼ /e/	***	***	**	***	-	-
/ɛ/ ∼ /a/	***	***	-	-	-	-
/ɛ/ ∼ /ɔ/	-	***	-	-	***	-
/ɛ/ ∼ /o/	***	***	-	-	-	-

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Table D.7 – *continued from previous page*

Comparison	F_1	F_2	F_3	Euclidean dist.	Duration	Spectral emph.
/ɛ/ ∼ /ʊ/	**	***	-	***	-	*
/ɛ/ ∼ /u/	***	***	-	***	-	***
/a/ ∼ /i/	***	***	***	***	***	***
/a/ ∼ /ɪ/	***	***	***	***	**	-
/a/ ∼ /e/	***	***	***	***	*	-
/a/ ∼ /ɛ/	***	***	-	-	-	-
/a/ ∼ /ɔ/	***	***	-	**	**	-
/a/ ∼ /o/	***	***	-	***	-	-
/a/ ∼ /ʊ/	***	***	-	***	-	*
/a/ ∼ /u/	***	***	-	***	-	***
/a/ ∼ /a+/	-	-	-	-	-	-
/ɔ/ ∼ /i/	***	***	***	***	-	***
/ɔ/ ∼ /ɪ/	***	***	***	***	-	-
/ɔ/ ∼ /e/	***	***	***	***	***	-
/ɔ/ ∼ /ɛ/	-	***	-	-	***	-
/ɔ/ ∼ /a/	***	***	-	**	**	-
/ɔ/ ∼ /o/	***	***	-	-	-	-
/ɔ/ ∼ /ʊ/	***	***	-	***	*	*
/ɔ/ ∼ /u/	***	***	-	***	*	***
/o/ ∼ /i/	***	***	***	***	*	**
/o/ ∼ /ɪ/	***	***	***	***	-	-
/o/ ∼ /e/	-	***	***	-	***	-
/o/ ∼ /ɛ/	***	***	-	-	-	-
/o/ ∼ /a/	***	***	-	***	-	-
/o/ ∼ /ɔ/	***	***	-	-	-	-
/o/ ∼ /ʊ/	***	-	-	***	-	-
/o/ ∼ /u/	***	**	-	***	-	**
/ʊ/ ∼ /i/	***	***	***	***	**	-
/ʊ/ ∼ /ɪ/	-	***	***	-	***	-
/ʊ/ ∼ /e/	**	***	***	-	**	-
/ʊ/ ∼ /ɛ/	***	***	-	-	-	*
/ʊ/ ∼ /a/	***	***	-	***	-	*

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Table D.7 – *continued from previous page*

Comparison	F_1	F_2	F_3	Euclidean dist.	Duration	Spectral emph.
/ʊ/ ∼ /ɔ/	***	***	-	***	*	*
/ʊ/ ∼ /o/	***	-	-	***	-	-
/ʊ/ ∼ /u/	***	-	-	-	-	-
/u/ ∼ /i/	-	***	***	***	***	-
/u/ ∼ /ɪ/	***	***	***	-	**	*
/u/ ∼ /e/	***	***	***	***	-	**
/u/ ∼ /ɛ/	***	***	-	***	-	***
/u/ ∼ /a/	***	***	-	***	-	***
/u/ ∼ /ɔ/	***	***	-	***	*	***
/u/ ∼ /o/	***	**	-	***	-	**
/u/ ∼ /ʊ/	***	-	-	-	-	-

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D.2 Descriptive statistics for glide data, Chapter 5

Table D.8: *Summary of duration results for intervocalic singleton and geminate glides by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in ms).*

C	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
j	604	93	94	22	33	158
jː	648	167	162	34	98	277
w	572	97	97	24	42	153
wː	560	163	160	33	79	280

Table D.9: *Summary of duration results for all vowels preceding singleton and geminate glides by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in ms).*

V	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
V before j	604	160	149	55	53	423
V before jː	648	122	116	41	44	287
V before w	572	154	152	50	52	306
V before wː	560	125	117	42	43	282

Table D.10: *Summary of duration results for /a/ tokens preceding singleton and geminate glides by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in ms).*

V	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
/a/ before j	289	154	143	54	53	342
/a/ before jː	285	119	115	41	44	287
/a/ before w	156	166	162	44	72	270
/a/ before wː	325	125	119	36	57	282

Table D.11: *Summary of F1 results for intervocalic singleton and geminate glides by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in Hz) at glide midpoints.*

C	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
j	604	441	430	67	245	691
jː	648	276	271	40	162	481
w	572	436	425	63	291	617
wː	560	305	306	52	155	518

Table D.12: *Summary of F2 results for intervocalic singleton and geminate glides by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in Hz) at glide midpoints.*

C	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
j	604	2312	2286	277	1763	2851
jː	648	2444	2324	270	1888	3000
w	572	792	786	100	518	1111
wː	560	676	667	105	402	1143

Table D.13: *Summary of F3 results for intervocalic singleton and geminate glides by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in Hz) at glide midpoints.*

C	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
j	604	3036	3034	266	2182	3740
jː	648	3228	3159	261	2776	4074
w	572	2742	2794	251	2072	3296
wː	560	2792	2888	305	1960	3444

Table D.14: *Summary of F1 results for /a/ tokens preceding singleton and geminate glides by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in Hz) at vowel midpoints.*

V	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
/a/ before j	289	450	432	73	304	691
/a/ before jː	285	273	266	41	179	481
/a/ before w	156	439	430	60	312	613
/a/ before wː	325	305	308	53	155	444

Table D.15: *Summary of F2 results for /a/ tokens preceding singleton and geminate glides by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in Hz) at vowel midpoints.*

V	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
/a/ before j	289	2276	2181	280	1802	2777
/a/ before jː	285	2447	2333	260	2050	2925
/a/ before w	156	801	798	97	639	1111
/a/ before wː	325	676	666	108	402	1044

Table D.16: *Summary of RMS amplitude results for intervocalic singleton and geminate glides by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in dB) at glide midpoints.*

C	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
j	604	67.89	68.16	3.82	55.37	78.86
jː	648	64.93	64.58	3.89	53.83	76.40
w	572	67.82	68.07	4.02	55.29	77.88
wː	560	64.79	64.41	3.75	53.73	79.44

Table D.17: *Summary of relative RMS amplitude results for intervocalic singleton and geminate glides by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in dB) at glide midpoints relative to RMS values at midpoints of preceding vowels.*

C	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
j	604	0.57	0.57	3.13	-19.08	9.73
jː	648	3.35	3.54	3.38	-6.56	14.82
w	572	0.52	0.40	2.89	-7.20	10.65
wː	560	3.44	3.81	3.77	-16.26	12.74

D.3 Descriptive statistics for tone data, Chapter 6

Table D.18: *Summary of f0 results for High, Low and Falling tones at 25%, 50% and 75% points in initial syllables (of disyllabic words) by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in Hz).*

Tone	at	n	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
High before Low	25%	100	142	19	138	110	185
	50%	100	144	21	140	108	192
	75%	100	143	22	140	107	194
High before High	25%	130	132	16	130	105	169
	50%	130	133	17	131	105	174
	75%	130	134	18	133	104	175
Falling before Low	25%	46	138	18	135	115	188
	50%	46	130	19	126	102	179
	75%	46	120	18	119	91	163
Low before Low	25%	131	124	17	123	93	175
	50%	131	124	18	122	89	178
	75%	131	123	19	120	86	181
Low before High	25%	79	120	16	125	91	145
	50%	79	120	16	126	89	147
	75%	79	120	16	126	89	154
Low before Falling	25%	142	120	14	119	95	154
	50%	142	120	16	118	94	157
	75%	142	122	17	118	95	162

Table D.19: *Summary of f0 results for High, Low and Falling tones at 25%, 50% and 75% points in final syllables (of disyllabic words) by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in Hz).*

Tone	at	n	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
High after Low	25%	78	137	18	142	103	172
	50%	78	139	17	144	105	177
	75%	78	138	17	139	105	179
High after High	25%	133	134	18	133	102	170
	50%	133	134	18	131	102	169
	75%	133	132	17	131	104	169
Falling after Low	25%	211	137	20	134	103	198
	50%	211	124	16	122	96	173
	75%	211	106	12	105	78	154
Low after Low	25%	159	119	17	115	90	171
	50%	159	113	15	111	85	165
	75%	159	105	11	103	82	155
Low after High	25%	107	110	14	110	84	142
	50%	107	103	11	105	81	128
	75%	107	97	10	97	78	119
Low after Falling	25%	46	107	14	105	86	131
	50%	46	103	12	101	85	124
	75%	46	98	12	95	79	119

Table D.20: *Summary of RMS amplitude results for High, Low and Falling tones at 25%, 50% and 75% points in initial syllables (of disyllabic words) by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in dB).*

Tone	at	n	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
High before Low	25%	100	69	4	69	60	80
	50%	100	70	5	70	59	82
	75%	100	70	5	70	58	82
High before High	25%	130	68	4	69	58	79
	50%	130	69	4	70	58	79
	75%	130	69	4	69	58	78
Falling before Low	25%	46	68	4	69	61	76
	50%	46	68	4	69	59	74
	75%	46	67	4	68	55	72
Low before Low	25%	131	68	5	68	57	79
	50%	131	68	5	69	57	79
	75%	131	68	5	69	57	80
Low before High	25%	79	67	4	67	57	75
	50%	79	67	4	67	56	75
	75%	79	67	4	67	56	75
Low before Falling	25%	142	66	4	67	54	78
	50%	142	67	5	68	54	77
	75%	142	67	5	68	54	77

Table D.21: *Summary of RMS amplitude results for High, Low and Falling tones at 25%, 50% and 75% points in final syllables (of disyllabic words) by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in dB).*

Tone	at	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
High after Low	25%	78	69	4	69	58	80
	50%	78	67	4	67	58	77
	75%	78	64	4	64	52	71
High after High	25%	133	68	5	68	55	77
	50%	133	66	5	67	55	78
	75%	133	63	5	63	53	77
Falling after Low	25%	211	69	5	69	56	82
	50%	211	67	5	67	56	81
	75%	211	62	5	62	50	78
Low after Low	25%	159	66	6	66	51	80
	50%	159	64	5	64	50	77
	75%	159	60	4	59	48	70
Low after High	25%	107	63	5	64	52	74
	50%	107	61	5	61	50	73
	75%	107	58	5	58	42	70
Low after Falling	25%	46	61	4	61	54	68
	50%	46	60	3	60	52	65
	75%	46	57	4	58	50	66

Table D.22: *Summary of duration results for High, Low and Falling tones in initial syllables (of disyllabic words) by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in ms).*

Tone	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
High before Low	100	192	75	163	83	448
High before High	130	179	60	166	85	390
Falling before Low	46	229	72	196	153	428
Low before Low	131	203	67	190	81	390
Low before High	79	194	85	160	103	399
Low before Falling	142	152	55	139	52	327

Table D.23: *Summary of duration results for High, Low and Falling tones in final syllables (of disyllabic words) by number of tokens (n) and mean ($\bar{x}$), median ($\tilde{x}$), standard deviation (σ), minimum and maximum (in ms).*

Tone	*n*	$\bar{x}$	$\tilde{x}$	σ	*min.*	*max.*
High after Low	78	158	51	154	81	306
High after High	133	152	47	150	60	325
Falling after Low	211	181	56	173	75	440
Low after Low	159	179	43	172	83	292
Low after High	107	106	31	100	52	207
Low after Falling	46	100	29	93	57	168