Temporal correlates of Lopit singleton and geminate glides

Rosey Billington

University of Melbourne

rbil@unimelb.edu.au

Abstract

Length contrasts among glides are typologically uncommon, and argued to be crosslinguistically dispreferred. Nevertheless, such contrasts are attested in various languages around the world, though phonetic explorations remain very limited. This paper presents selected findings pertaining to glides in Lopit, an Eastern Nilotic language for which a length distinction has been proposed for palatal and labiovelar glides. Duration values are compared for intervocalic tokens of putative geminates /wː/ and /jː/ and singletons /w/ and /j/, and for vowels preceding them, and indicate that in Lopit, duration is a major correlate distinguishing glides at the same place of articulation.
Index Terms: geminate, length, glide, duration, Nilotic

1. Introduction

1.1. Glides and geminate typology

Crosslinguistic surveys of consonant gemination[1] note enormous diversity in quantity contrasts in the world's languages, 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 length. Glides such as [w] and [j] are among the least likely segments to be found geminated [1]. A relationship between sonorancy and the markedness of geminacy has been proposed, with suggestions that the spectral continuity of glides in relation to adjacent vowels likely hinders the perception of differences in constriction duration [2]. It has also been suggested that in production, phonemic differences in duration may be less robust for glides than for other manners of articulation [3]. However, very little acoustic phonetic research has taken place to examine the characteristics of geminate compared to singleton glides which, despite their rarity (and in some cases presumed impossibility), are described for various Indo-European, Finno-Ugric, Dravidian, Austronesian, Oto-Manguean, Afro-Asiatic, Niger-Congo, and Nilo-Saharan languages [1].

1.2. Geminate consonants in Lopit

Existing observations for Lopit, an Eastern Nilotic (Nilo-Saharan) language of South Sudan and its diaspora, all include proposals that some consonants of the same place, manner and voicing have a distinction involving, to some extent, length differences [5] [6] [7]. Data collected in the wider documentation project this study is part of similarly point to such a contrast which, based on impressions of length, has been referred to as a contrast between geminates, such as /tː, dː, nː, lː, rː, wː, jː/, and singletons, such as /t, d, n, l, ɾ, w, j/. With the exception of /tː, t/, alveolar length contrasts in Lopit have a low functional load, but for the glides, both putative geminate /wː, jː/ and singleton /w, j/ are found reasonably often, and the contrast is present word-initially as well as word-medially. Lopit is one of several Eastern Nilotic languages for which glide contrasts variously described as involving length or strength are proposed, though none have been the subject of phonetic investigation. For at least the long/strong labiovelar glides in Eastern Nilotic, an origin in stop-glide sequences has been tentatively suggested [5].

[1] Here referring only to contrastive differences in consonant length.

1.3. Phonetic correlates of gemination

Across languages, the most consistent phonetic correlate of consonantal length contrasts is constriction duration, which, given that most studies investigate obstruent length, generally refers to the period of complete closure between articulators. Overviews show that geminate consonants reliably have higher duration values than singletons, and furthermore, that vowels preceding geminate consonants often have lower duration values [8] [9] [10], though in some cases they may be no different, or may be longer [11] [10]. For stops, geminates are generally 1.5-3 times longer than singletons [12], and while very little duration data is available crosslinguistically for glides, findings for geminate glides in languages such as Buginese, Madurese, Lebanese Arabic, Egyptian Arabic, Persian, and Guinaang Bontok seem to accord with this pattern, being approximately 1.4-2.6 times longer than singletons [13] [14] [15] [3] [2]. Where reported, differences on the basis of other acoustic measures are also often found for geminates compared to singletons, indicating that additional language-specific cues may support length contrasts.

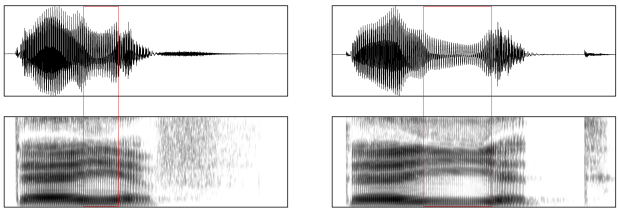
2. Research aim

Given that a contrast between two types of labiovelar glide and two types of palatal glide has been proposed for Lopit, and that impressionistic observations suggest that glides at the same place of articulation may be either short or long, the primary aim of this study is to establish whether the temporal characteristics of putative /wː, jː/ and /w, j/ are indicative of a contrast involving length. The focus of this paper is on the constriction duration of intervocalic glides, and the duration of vowels preceding them. Amplitude and formant measures are also considered in ongoing work, but are not reported here.

3. Method

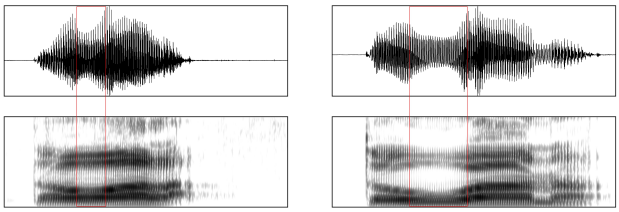
3.1. Participants

The participants in this study were five adult speakers of the Dorik dialect of Lopit: three men (AL, DA, VH) and two women (EA, JT). They are part of a small Lopit community in Melbourne, Australia, whose members arrived in Australia from 2000 onwards. All are multilingual, as is common in South Sudan; additional languages include English and Juba Arabic, but Lopit is the primary language used at home.



(a) (b)

Figure 1: *Spectrogram and waveform (880 ms) for palatals in (a) [tɛ́jɛ̀f] "IMP.chop" and (b) [tɛ́jːɛ̀t] "IMP.pull".*



(a) (b)

Figure 2: *Spectrogram and waveform (800 ms) for labiovelars in (a) [tɔ́wálàʔ] "IMP.cough" and (b) [tɔ́wːánàʔ] "IMP.stay".*

3.2. Materials and procedures

A large set of nouns and verbs containing intervocalic examples of /wː/, /jː/, /w/, and /j/ was compiled as stimuli, drawn from the database constructed in the course of the wider project. The words had a range of tonal patterns, and were of mainly 2-3 syllables (with some 4-syllable words); those used in the analysis had glides flanked by non-close vowels /e, ɛ, o, ɔ/ and particularly /a/ [4]. Each word was recorded 5 times in isolation, with occasional additions or omissions, following a spoken English prompt (simultaneously shown on a laptop screen). 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. While the possibility of frication among Lopit geminate glides has been suggested [6], and it was anticipated that this may necessitate the exclusion of some tokens (as they would be unsuitable for the spectral analyses being performed in ongoing work), this was only the case for one hyperarticulated token. Others were excluded for different reasons affecting formant tracking (coughing, creakiness, or formants simply being too weak). The final dataset contained 2384 token representing 91 words (/j/ = 604, /jː/ = 648, /w/ = 572, /wː/ = 560).

3.3. Data processing and analysis

Data were labelled with reference to wideband spectrograms and corresponding waveforms (e.g. Figures 1 and 2) in Praat [16]. Labelling of glides is known to be a challenge. While some previous studies of glides and gemination have used formant cues as the primary criteria for segmentation, from a generous approach taking the period between the end and beginning of steady states of neighbouring vowels [3] to a more conservative approach targeting glide steady states [15], in this study amplitude criteria were taken as the primary indicators of the constriction period of glides. Glides are known to correlate with an overall drop in amplitude, in addition to reduced amplitudes for F2-F4 (particularly F3 for labiovelar glides, and F2 for palatal glides) [17] [18]. These cues are argued to provide the most reliable landmarks for boundaries between glides and vowels, e.g. in automatic segmentation [19], and have been utilised in some studies of singleton and geminate glides [14]. As such, glides in the present data were labelled based on marked changes in overall and upper formant amplitude relative to adjacent vowels. Labelled data were imported into the Emu Speech Database System [20], and duration measures were queried and plotted in the R software environment [21] and statistically tested with Linear Mixed-Effects Models (discussed further below) and post-hoc Tukey HSD tests, using the `lme4` package [22].

4. Results

4.1. Duration of glides

Duration values for /wː/, /jː/, /w/, and /j/ were compared, and, as shown in Figure 3, clear and consistent differences between /wː/, /jː/ and /w/, /j/ can be observed across the five participants, with higher duration values apparent for geminates /wː/, /jː/ compared to singletons /w/, /j/. 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, following comparisons between different models. A likelihood ratio test shows the effect of glide category is significant (χ^2(3, N=2384)= 250.87, p<0.001). Post-hoc tests reveal that duration differences between geminate glides and their singleton counterparts are significant; geminate labiovelar /wː/ is an estimated 65 $\pm$ 4 ms longer than singleton labiovelar /w/ (p<0.001), and geminate palatal /jː/ is an estimated 74 $\pm$ 4 ms longer than singleton palatal /j/ (p<0.001). Geminate labiovelar /wː/ is also 67 $\pm$ 4 ms longer than singleton palatal /j/ (p<0.001), and geminate palatal /jː/ is 72 $\pm$ 4 ms longer than singleton labiovelar /w/ (p<0.001). There are no significant duration differences between geminate /wː/ and geminate /jː/ (p=0.318), nor between singleton /w/ and singleton /j/ (p=0.945).

For these medial glides in words produced in isolation, duration values are high in general; means for the singletons /w/ and /j/ are 97 ms (sd 24 ms) and 93 ms (sd 22 ms) respectively, and means for geminates /wː/ and /jː/ are 163 ms (sd 33 ms) and 167 ms (sd 34 ms). There is slightly more variation in duration values for geminate glides, some of which is likely related to word length, as shown in Figure 4; a test of the effect of glide length categorised by occurrence in two-syllable compared to 3-syllable words (χ^2(7, N=2251)= 277.91, p<0.001) shows the same significant and substantial duration differences between geminates and singletons, but also shows that geminate glides in two-syllable words (in which they are onsets of the second syllable) are significantly longer than those in three-syllable words (in which they are mostly also onsets of the second syllable, but sometimes of the third) by 29 $\pm$ 4 ms for /jː/ (p<0.001) and 15 $\pm$ 5 ms for /wː/ (p<0.05). Interestingly, there are no duration differences for the singletons in two-syllable compared to three-syllable words. Overall, geminate glides are 1.77 times longer than singleton glides. Some differences in the ratios of singleton to geminate duration can be observed, as shown in Table 1; geminate labiovelars are 1.71 times longer than singletons, while geminate palatals are 1.82 times longer, and, although the factor of sex did not make any difference to the statistical model, the two female participants (EA and JT) tend towards slightly higher duration values for singleton glides and accordingly have lower singleton to geminate duration ratios.

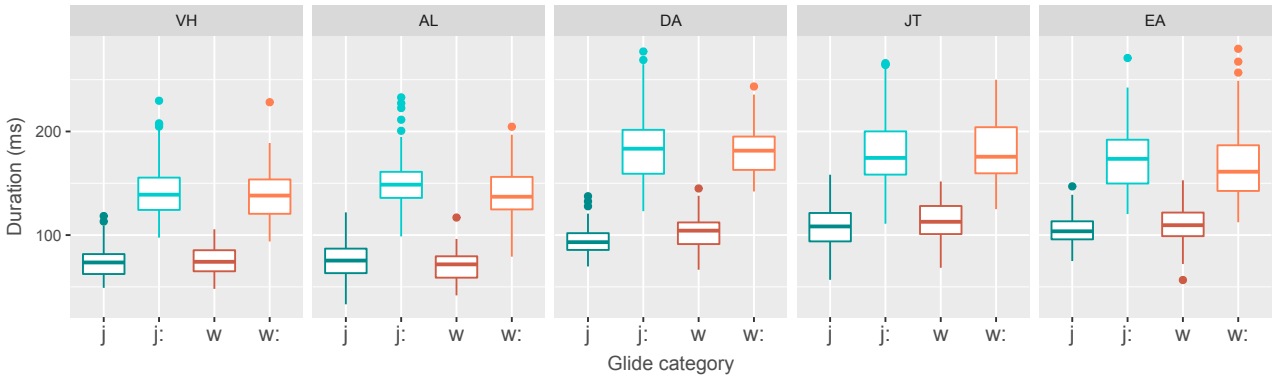


Figure 3: *Duration of proposed singleton and geminate glides in Lopit, for each participant.*

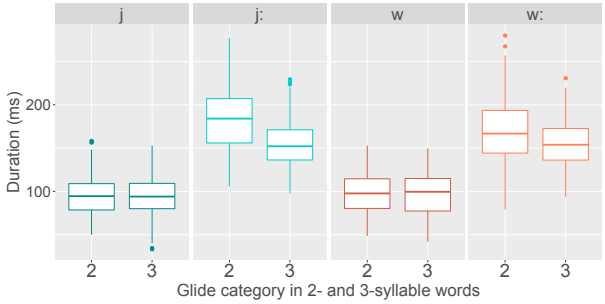


Figure 4: *Duration of singleton and geminate glides in 2-syllable and 3-syllable words, for all participants.*

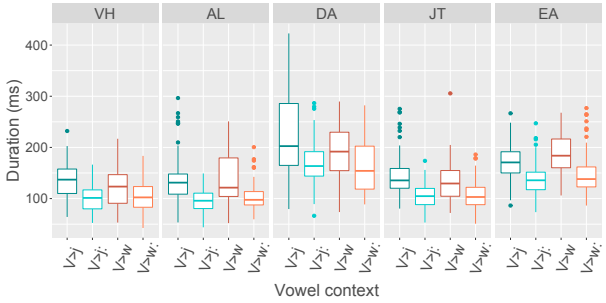


Figure 5: *Duration of vowels preceding singleton and geminate glides in Lopit, for each participant.*

Table 1: *Singleton to geminate duration ratios.*

participant	/w/ : /w:/	/j/ : /j:/	/C/ : /C:/
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**

4.2. Duration of vowels preceding glides

Duration values for vowels preceding glides were also compared, and, as seen in Figure 5, there is more variability, but also an apparent tendency towards lower duration values for vowels preceding geminate glides. The effect of glide category was investigated using a mixed-effects model as above, and glide category was found to have a significant effect (χ^2(3, N=2384)= 36.19, p<0.001). In addition, a subset of the data containing only tokens of /a/ was checked, to see if patterns were similar without the possibility of minor duration differences by vowel quality, and the effect of glide category was also significant in this case (χ^2(3, N=1055)= 21.05, p<0.001). Both tests confirm that vowels preceding geminate glides have lower duration values than those preceding singletons; preceding /w:/, vowels are an estimated 28 ± 7 ms shorter than those preceding /w/ (p<0.001), or 37 ± 11 ms shorter when only /a/ tokens are considered (p<0.01), and vowels preceding /j:/ are 34 ± 7 ms shorter than those preceding /j/ (p<0.001), or 34 ± 9 ms shorter for the /a/ subset (p<0.01). In both the test with all vowels and with only open vowels, there are no significant differences in duration between vowels preceding the two geminates /w:/ and /j:/ (p=1.00; p=0.93), nor between vowels preceding the two singletons /w/ and /j/ (p=0.81; p=0.83).

Mean values for vowels preceding /w:/ are 125 ms (sd 42 ms) for all vowels, or 125 ms (sd 36 ms) for only open vowels, and similar for those preceding /j:/, with a mean of 122 ms (sd 41 ms) for all vowels and 119 ms (sd 41 ms) for only open vowels. Means for vowels preceding singleton /w/ are 154 ms (sd 50 ms) for all vowels, or 166 ms (sd 44 ms) for open vowels, and preceding /j/, means are 160 ms (sd 55 ms) for all vowels and 154 ms (sd 54 ms) for open vowels. Vowels preceding singleton palatals are therefore 1.3 times longer than those preceding geminates, and vowels preceding singleton labiovelars are 1.24 times longer; taking both places of articulation together, vowels preceding singleton glides are 1.27 times longer. There are no substantial differences in the duration ratios for individual speakers. While there are hints that segmental and tonal factors may have some influence on preceding vowel durations (for example, high duration values for the small number of vowels with Falling tones), results are for the most part inconsistent except in the case of word length, for which there is a pattern of longer preceding vowels in two-syllable compared to three-syllable words, suggesting a well-attested effect of polysyllabic shortening. When tested statistically (χ^2(7, N=2251)= 118.01, p<0.001), the differences are significant among the singletons, with vowels preceding /j/ being an estimated 47 ± 7 ms longer in two-syllable compared to three-syllable words (p<0.001), and vowels preceding /w/ being an estimated 35 ± 7 ms longer in two-syllable words (p<0.001). Vowels preceding geminate /w:/ are 25 ± 7 ms longer in two-syllable words (p<0.01), but there are no significant duration differences by word length for for vowels preceding /j:/ (p=0.14).

5. Discussion and conclusions

Taken together, these results show that constriction duration is a robust correlate of glide category in pairs of palatal and labiovelar Lopit glides; substantially higher duration values are found for /w:/ and /j:/ compared to /w/ and /j/. Furthermore, geminate glides at both places of articulation are similarly distinct in relation to singletons, suggesting that they are subject to a shared pattern in the consonant inventory. These quantitative findings lend support to impressionistic observations of a length contrast among Lopit glides [5] [6] [7], and bolster arguments that while length contrasts among glides are less common, they have a significant role in the phonologies of some languages [1]. In this data for Lopit, glides /w:/ and /j:/ are overall 1.77 times longer than /w/ and /j/, a ratio in the realm of what is typically observed for geminate compared to singleton consonants [12], and specifically for glide contrasts of this sort in other languages [13] [14] [15] [3] [2]. The trend towards lower duration values for vowels preceding geminates in Lopit also aligns with what is often (though not always) observed for vowels preceding geminate segments in other languages.

This evidence of significant glide duration differences provides a useful starting point for further exploration of consonant length in Lopit as language documentation work continues [23]. Ongoing phonetic research will be well-placed to examine in more detail how the realisation of Lopit glides is mediated by other segmental and prosodic factors, such as word length, given the polysyllabic shortening evident in some of the comparisons discussed here, or vowel quality and tone, which are other aspects of Lopit phonetics and phonology currently receiving close attention [4] [24]. In particular, given that geminate glides are permitted to occur word-intially (albeit infrequently) in contrast with singletons, differences in the production of a typologically less common length contrast in a typologically less common word position for a length contrast will likely offer fruitful insights. However, an obvious next step is to investigate the nature of other proposed length contrasts, all alveolar, at different manners of articulation in Lopit. These other possible length contrasts are found in fewer other Eastern Nilotic languages than the glide contrasts, and may well have a different provenance than the original consonant sequences tentatively proposed for long glides [5].

Finally, it is worth noting that while duration is a clear correlate distinguishing Lopit glides at the same place of articulation, it is unlikely to be the only correlate; additional impressions noted for Lopit [6] and other Eastern Nilotic languages hint at the possibility of articulatory differences, which would not be unexpected for geminate consonants more generally, nor for other consonant types correlating with longer durations. While not addressed here, formant and amplitude measures indicate that speakers of Lopit may be provided with extra cues to the contrast. The role of such cues, in addition to duration, is worth consideration in typological work assessing the robustness of glide length contrasts in both perception and production.

6. Acknowledgements

I wish to thank members of the Lopit community for contributing their time and knowledge to this project, Janet Fletcher for advice and comments on this work, and Jonathan Moodie for illuminating discussions of Lopit morphosyntax. Support from ARC grant DP0984419, the University of Melbourne School of Languages and Linguistics, and the ARC Centre of Excellence for the Dynamics of Language is gratefully acknowledged.

7. References

[1] Maddieson, I., "Glides and gemination", Lingua, 118:1926–1936, 2008.

[2] Kawahara, S., "Sonorancy and geminacy", in L. Bateman, A. Werle, E. Reilly and M. O'Keefe [Eds], Univ. Massachusetts Occasional Papers in Linguistics 32: Papers in Optimality Theory III, 145-186, GLSA, 2007.

[3] Aoyama, K. and Reid, L. A., "Cross-linguistic tendencies and durational contrasts in geminate consonants: An examination of Guinaang Bontok geminates", J. of the Int. Phonetic Assoc., 36(2):145–157, 2006.

[4] Billington, R. "'Advanced Tongue Root in Lopit: Acoustic and ultrasound evidence"', in J. Hay and E. Parnell [Eds], Proceedings of the 15th Australasian Int. Speech Science and Technology Conf., 119–122, ASSTA, 2014.

[5] Vossen, R., The Eastern Nilotes: Linguistic and historical reconstructions, Dietrich Reimer Verlag, 1982.

[6] Turner, D., Lopit phonology, SIL-Sudan, 2001.

[7] Stirtz, T., Phonological comparison of Lopit dialects, SIL-South Sudan, 2014.

[8] Ridouane, R., "Gemination at the junction of phonetics and phonology", Laboratory Phonology 10:61–90, 2010.

[9] Hamzah, H., "The acoustics and perception of the word-initial singleton/geminate contrast in Kelantan Malay", PhD thesis, Univ. Melbourne, 2013.

[10] Kawahara, S., "The phonetics of *sokuon*, or geminate obstruents", in H. Kubozono [Ed], Handbook of Japanese phonetics and phonology, 43–78, Mouton, 2015.

[11] Ham, W. H., Phonetic and phonological aspects of geminate timing, Routledge, 2001.

[12] Ladefoged, P. and Maddieson, I., The sounds of the world's languages, Blackwell, 1996.

[13] Cohn, A.C., Ham, W. H., and Podesva, R. J. "The phonetic realization of singleton-geminate contrasts in three languages of Indonesia", in J. J. Ohala [Ed], Proceedings of the 14th Int. Congress of Phonetic Sciences, 587–590, Univ. California Press, 1999.

[14] Khattab, G. and Al-Tamimi, J., "Geminate timing in Lebanese Arabic: The relationship between phonetic timing and phonological structure", Laboratory Phonology 5(2):231–269, 2014.

[15] Hansen, B.B., "The perceptibility of duration in the phonetics and phonology of contrastive consonant length", PhD thesis, Univ. Texas at Austin, 2012.

[16] Boersma, P. and Weenink, D., Praat: Doing phonetics by computer [Computer program]. Version 5.2.35. Online: http://www.praat.org/, accessed 28 August 2011.

[17] Espy-Wilson, C.Y., "Acoustic measures for distinguishing the semivowels /w j r l/ in American English", J. of the Acoustical Soc. of America 92(2):736–757, 1992.

[18] Harrington, J. & Cassidy, S., Techniques in Speech Acoustics, Springer Science & Business Media, 1999.

[19] Hunt, E. H., "Acoustic Characterization of the Glides /j/ and /w/ in American English", PhD thesis, MIT, 2009.

[20] Cassidy, S. and Harrington, J., "Multi-level annotation in the Emu speech database management system", Speech Commun. 33:61–77, 2001.

[21] R Core Team, R: A language and environment for statistical computing [Computer program]. Version 2.15.0 and 3.2.5. Online: http://www.R-project.org, accessed 16 April 2012/22 April 2016.

[22] Bates, D., Maechler, M., Bolker, B., and Walker, S., "Fitting Linear Mixed-Effects Models Using lme4", J. of Statistical Software, 61(1):1–48, 2015.

[23] Moodie, J., "A grammar of Lopit", PhD thesis, Univ. Melbourne, in progress.

[24] Billington, R. "Lexical tone in Lopit", in The Scottish Consortium for ICPhS 2015 [Ed], Proceedings of the 18th Int. Congress of Phonetic Sciences, paper 0755. 1-4, Univ. Glasgow, 2015.