Glide Formation in Kinande Does Not Neutralize an Underlying [ATR] Contrast

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1. Introduction

Unlike most other modern Bantu languages, Kinande has faithfully preserved the Proto-Bantu contrast between [-ATR] and [+ATR] high vowels (Hyman, 2002). As a result, while other Bantu languages typically have only two contrastive high vowels (i.e. high back and high front), Kinande has four: [-ATR] [i u] and [+ATR] [į ų].[1] These four high vowels, together with mid [e o] and low [a], are laid out in a vowel chart in (1) below. The fact that they are contrastive is demonstrated in (2): as shown, each of these vowels may appear as the initial vowel of an imperative verb.[2]

(1) Contrastive vowels of Kinande

high	į i		ų u
mid	e		o
low		a	

(2) Imperative verb forms illustrating Kinande's contrastive vowels

a.	[į]	įta	'kill!'
b.	[i]	iga	'learn!'
c.	[ų]	ųta	'pour!'
d.	[u]	uma	'dry!'
e.	[e]	ega	'scratch!'
f.	[o]	owa	'listen!'
g.	[a]	anza	'love!'

The retained contrast between [-ATR] and [+ATR] high vowels sets the stage for one of the most well-studied phenemena of Kinande phonology: a process of vowel harmony in which [+ATR] features spread leftward (and also occasionally rightward) from the [+ATR] high vowels to which they underlyingly belong (Archangeli and Pullyblank 1994, 2002; Gick et al. 2006; Kenstowicz 2009; Mutaka 1994, 1995). This process occurs, for example, whenever a verb root is augmented with the nominalizing suffix ***-į***: as shown in (3) below, the [+ATR] feature belonging to this suffix spreads leftward onto the vowels of the verb root, even if those vowels are non-high [e] [o] or [a]. In (4), we see [ATR] harmony in underived nominals; there, the presence of a final [+ATR] vowel in the root causes preceding vowels – again, including [e] [o] and [a] – to be realized as [+ATR] as well.[3]

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[1] Throughout, I follow the conventions of Kinande orthography rather than those of the IPA. Thus, [+ATR] vowels are transcribed with a dependent hook (e.g. **į**), IPA [j] is transcribed as **y**, and IPA [ɾ] is transcribed as **r**.

[2] The simple imperative in Kinande contains just the verb root and a final *-a-a* sequence which I (following standard practice) transcribe simply as *-a*.

[3] In nouns (including infinitives) [+ATR] spreads obligatorily throughout the root and also onto the immediately preceding noun class prefix, but only optionally onto the "pre-prefix" (Archangeli and Pulleyblank, 2002).

(3) [ATR] harmony in agentive nouns derived from the verb roots in (2)

a.	[ị]	/ịt/	'kill'	ọmw-ịtị/omw-ịtị	'killer'
b.	[i]	/ig/	'learn'	ọmw-ịgị/omw-ịgị	'learner'
c.	[ụ]	/ụt/	'pour'	ọmw-ụta/omw-ụta	'pourer'
d.	[u]	/um/	'dry'	ọmw-ụmị/omw-ụmị	'drier'
e.	[e]	/eg/	'scratch'	ọmw-ẹgị/omw-ẹgị	'scratcher'
f.	[o]	/ow/	'listen'	ọmw-ọwị/omw-ọwị	'listener'
g.	[a]	/anz/	'love'	ọmw-ạnzị/omw-ạnzị	'lover'

(4) [ATR] harmony in underived nouns triggered by root-final [ị] and [ụ]

a.	[ị]	/o-mú-kalị̀/	→	omụ́kạlị̀	'woman'
b.	[ụ]	/a-má-nakụ̀/	→	amạ́nạkụ̀	'desire to eat meat'

In all of the examples above, the segments responsible for triggering [ATR] harmony appear on the surface as [+ATR] vowels. In many circumstances, however, the triggers of harmony are realized as glides. For example, when **omwẹgị** 'scratcher' (from root **-eg-**) and **omwịgị** 'learner' (from root **-ig-**) are pronounced phrase-medially before a word beginning with [a], their final [ị] vowels are realized as high front glides. Interestingly, however, the simple fact that these vowels undergo glide formation does *not* prevent them from triggering [ATR] harmony: thus, both of the root vowels in (5) below bear a non-underlying [+ATR] feature, despite the fact that they are not followed (on the surface) by any [+ATR] vowel. In (6), we see that similar facts obtain when glide formation occurs word-internally: the underlying [ATR] contrast between the verb roots **-lu-** 'fight' and **-lụ-** 'leak' is therefore reflected in the presence or absence of vowel harmony, even though the root vowels which bear this contrast underlyingly are both realized as glides.

(5) Glide formation of final [+ATR] vowels does not block [ATR] harmony

a.	/o-mw-eg-ị akámuhuma(g)a/	→	omwẹgy akámuhumâ	'the scratcher hits him'
b.	/o-mw-ig-ị akámuhuma(g)a/	→	omwịgy akámuhumâ	'the learner hits him'

(6) Word-internal glide formation of root-final vowels does not block [ATR] harmony

a.	/mó-tu-ká-lu-ag-a/	→	mótukálwâ	'we fought (earlier today)'
b.	/mó-lu-ká-lụ-ag-g/	→	mọ́lụkạ́lwâ	'it leaked (earlier today)'

At first sight, the relationship between glide formation and [ATR] harmony in Kinande appears to be one of counterbleeding opacity, in which [ATR] harmony occurs in the absence of any surface trigger. This view is supported by Kinande orthographic conventions, in which vowels are marked for [ATR], but not glides. Another possibility, however, is that surface glides retain the [ATR] specifications of the vowels from which they are derived; if this is the case, then glides might trigger [ATR] harmony in the same way that vowels do, in a way that is entirely transparent. Evidence for this latter possibility is found in the intuitions of native speakers. Ngessimo Mutaka, for example, writes in the introduction to the *Kinande/Konzo - English Dictionary with an English - Kinande/Konzo Index* (p. xlvi):

> I would like to hereby confirm what [Kambale - PJJ] Kavutirwaki told Claire Grégoire, that he could perceive clearly the ATR-ness of a glide as in erịhekyâ 'to make carry.' It is as if one was still pronouncing the "ị" sound in the glide. Claire Grégoire told me this piece of information in a personal communication, as she was astonished that a glide could be an ATR-bearing unit.

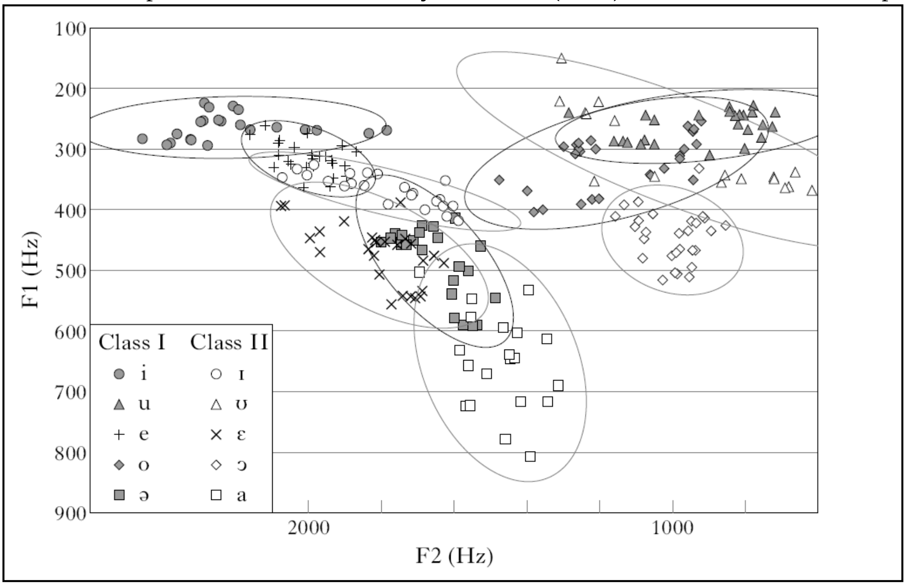
The above statement strongly suggests that (at least some) native speakers are able to perceive an [ATR] contrast in glides. We might expect, therefore, to find evidence for this contrast in the glides' acoustic realizations. In this paper, I present evidence of just this sort. Specifically, I discuss the results of an experiment designed to test whether or not the first and second formant values of high front glides derived from [+ATR] [ị] differ significantly from the first and second formant values of high front glides derived from [-ATR] [i]. The results of the experiment indicate that they do, and so corroborate the impressionistic judgments of Mutaka and Kavutirwaki.

2. Acoustics Experiment

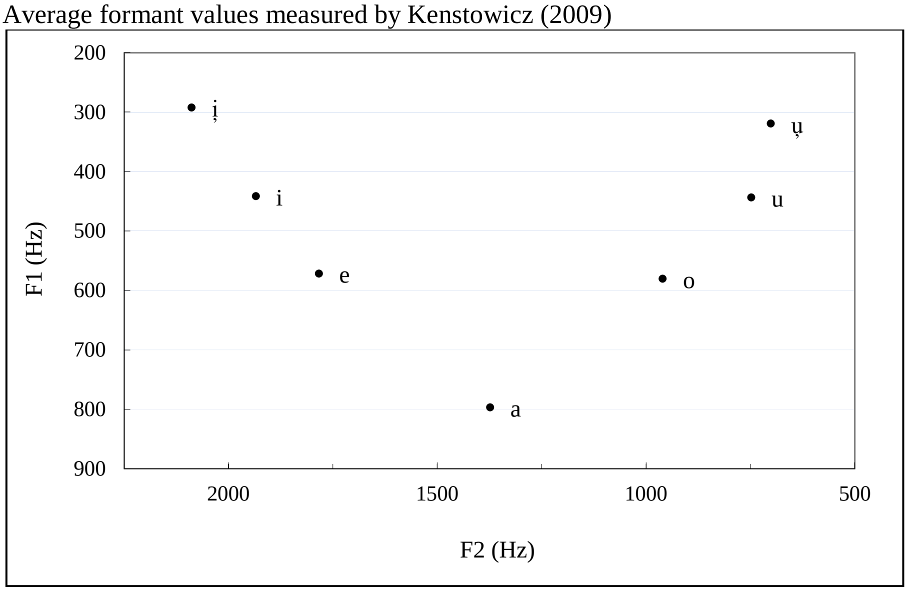
2.1. Background Research

Informing the design of this experiment were studies by Gick et al. (2006) and Kenstowicz (2009), who investigated the acoustic correlates of [ATR] in Kinande vowels. Gick et al. measured F1 and F2 values for all 10 surface vowels of Kinande, while Kenstowicz measured values for the seven contrastive vowels presented in (1). As can be readily observed in the formant plots below, both studies found that [+ATR] high vowels, particularly [+ATR] high *front* vowels, occur closer to the periphery of the vowel space than their [-ATR] counterparts. That is, in both studies, [+ATR] [į] was found to differ from [-ATR] [i] in having a *lower* value for F1 and a *higher* value for F2. The F1 difference was found to be significant both by Kenstowicz and by Gick et al., and the F2 difference was found to be significant by Kenstowicz (Gick et al. do not discuss the significance of F2).

(7) F1xF2 scatterplot of values measured by Gick et al (2006), w/ 95% confidence ellipses[4]



(8) Average formant values measured by Kenstowicz (2009)



[4] In this chart, taken directly from Gick et al. (2006), [-ATR] and [+ATR] vowels are presented as IPA lax and tense vowels, respectively.

2.2. Experimental hypotheses

As just seen, F1 and F2 are quite reliable acoustic correlates of [ATR] in Kinande high front vowels. Since much (if not all) of these vowels' formant structure is also present in high front *glides*, it is reasonable to expect that if these glides were to contrast in [ATR], then they should also show significant differences in F1 and F2. More specifically, if high front glides maintain a surface [ATR] contrast, and if this contrast is acoustically cued in the same way that it is in vowels, then the two hypotheses in (9) should be confirmed.

(9) Predicted acoustic effects of an [ATR] contrast in glides
  a. The mean F1 of glides derived from [+ATR] [ị] should be significantly *lower* than the mean F1 of glides derived from [-ATR] [i]
  b. The mean F2 of glides derived from [+ATR] [ị] should be significantly *higher* than the mean F2 of glides derived from [-ATR] [i]

These two hypotheses were tested in the experiment described below.

2.3. Experimental methods: materials, procedure and subject

In order to test the hypothesis that glides derived from [+ATR] [ị] ([ị]-glides) have lower F1 values and higher F2 values than glides derived from [-ATR] [i] ([i]-glides), F1 and F2 measurements of [i]-glides and [ị]-glides in comparable segmental and prosodic contexts were obtained as follows. First, in consultation with a native speaker of Kinande (on whom see below), a set of 62 stimulus words was developed, consisting of 31 minimal or near-minimal pairs whose items differed (relevantly) in whether their final segment was [i] or [ị]. Two example pairs are given in (10) below; as shown there, members of each pair were controlled for syllable count and identity of the pre-[i]/[ị] consonant (cluster), but not for tone. A full list of stimuli is given in the Appendix.

(10) Examples of (near)-minimal pairs used in the experiment

a.	omú-káli	'fierce person'	*vs.*	omụ́-kạlị	'woman'
b.	omú-kámbi	'sugar cane residue'	*vs.*	olụ-thạ́mbị	'dynamite'

The 62 words of the stimulus set were then elicited, in random order without filler material, from the same native speaker. For this purpose, no written word list was used; instead, glosses of the desired target word were read aloud, after which the speaker incorporated the target word into two different sentence frames. First, he pronounced the word once in the sentence frame in (11); this frame placed the target word in utterance-final position, a context where it is pronounced essentially as it is in isolation. He then pronounced the word twice in the frame given in (12). This frame placed the target word immediately before the vowel [a], in which context the word's final [i] or [ị] vowel was forced to undergo glide formation. This second frame, then, produced the basic acoustic data analyzed in the experiment: 124 tokens of glides derived from [i] and [ị] (2 tokens/glide x 62 glides).

(11) Frame sentence 1: stimulus word is utterance-final, no glide formation

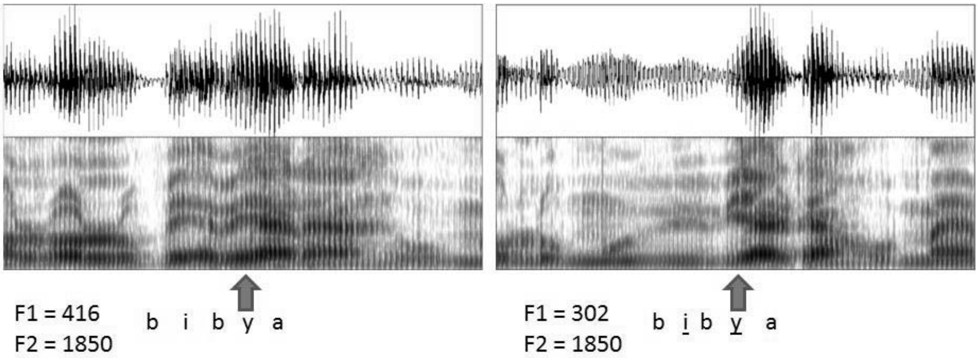
Omúlume	mwákáhul'	[TEST WORD].
The man	talked about	[TEST WORD].

(12) Frame sentence 2: stimulus word is utterance-medial, with glide formation

Omúlumy	oy' ulyáhul'	[TEST WORD]	ályahum'	émbene.
The man	who talked about	[TEST WORD]	hit	a goat.

All of the elicited utterances were recorded directly to digital audio using a portable digital recorder. The software program PRAAT (Boersma and Weenink 2008) was then used to measure the recorded glides' first and second formant values. Since glides (by definition) tend not to have the stable sustained formants characteristic of vowels, their formants - both F1 and F2 - were consistently measured at the earliest point where F2 reached a local maximum. This is illustrated below in (13).

(13) Measurements of glides derived from **olú-bíbi** ‘limit of a field’ and **omú-bibi** ‘sower’

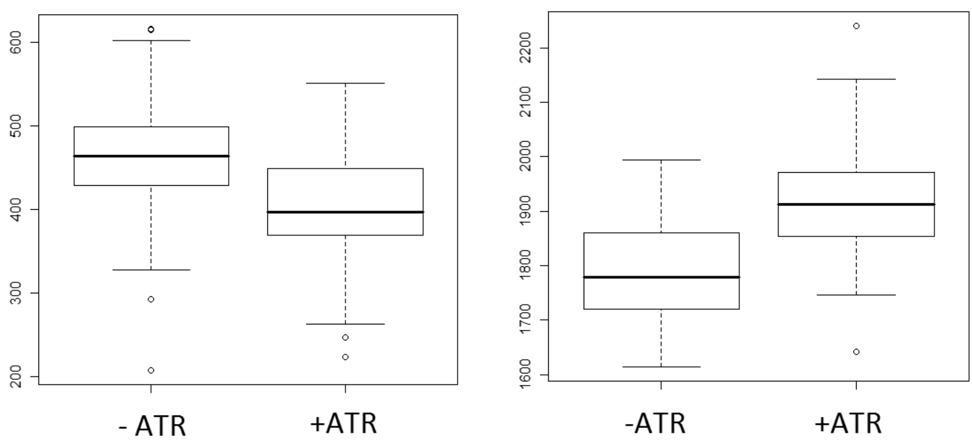


The subject of this experiment was a male native speaker of Kinande whose linguistic background includes knowledge of Swahili, Lingala, English, and French, combined with university study in African languages and linguistics. Not surprisingly, he was *not* naive to the purpose of this experiment; he recognized it immediately.

2.4. Results

A visual summary of the experimental results is presented in (14) below, where the measured F1 and F2 values of glides derived from [i] and [ị] are plotted in box-and-whiskers plots showing the distribution of the data by quartiles (with outliers excluded). As is readily apparent from these plots, the range of F1 values of glides derived from [+ATR] [ị] is considerably lower than the range of F1 values measured for [-ATR] [i], while the range of measured F2 values is considerably higher.

(14) a. Effect of underlying [ATR] on glide F1 b. Effect of underlying [ATR] on glide F2



Mean F1 and F2 values of the glides are presented in (15). As one would expect given the plots above, the mean F1 of glides derived from [+ATR] [ị] is less than the mean F1 of glides derived from [-ATR] [i], and the mean F2 is higher. 2-way repeated measures ANOVAs, with [ATR] as a within-subject effect of segmental context, show these differences to be statistically highly significant.

(15) Mean F1 and Mean F2 of glides derived from [i] and [ị]

	[i]-glides	[ị]-glides	
Mean F1 (Hz)	463	402	$p < 0.01$
Mean F2 (Hz)	1787	1916	$p < 0.01$

These results, showing the F1 and F2 values of glides derived from [ị] to differ significantly from the F1 and F2 values of glides derived from [i], are just those predicted by the hypotheses presented in 2.2.

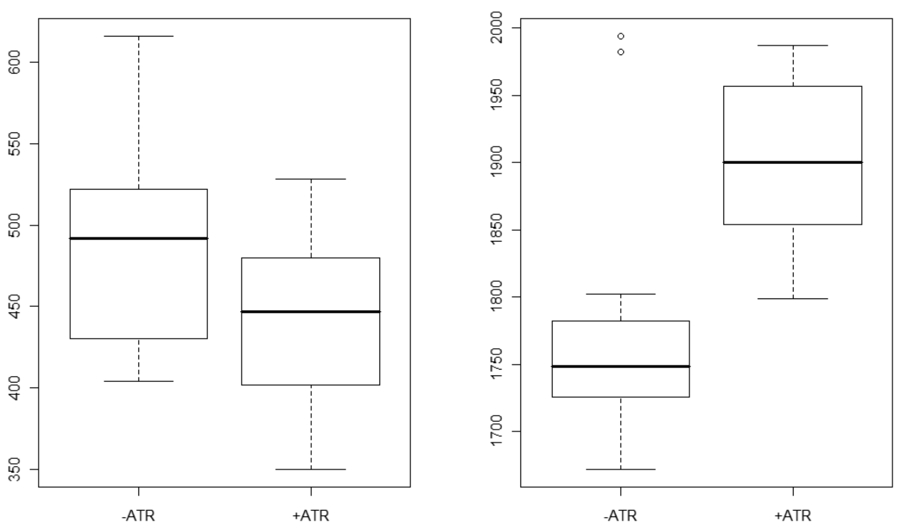
2.5. Considering co-articulation

In deciding how best to interpret the results presented above, it is important to recognize that in all of the words elicited in the experiment, glides derived from [-ATR] [i] and glides derived from [+ATR] [i̘] occur in systematically different vocalic contexts: in particular, due to [ATR] harmony, the vowels preceding [i̘]-glides are always [+ATR], while those preceding [i]-glides are always [-ATR]. This systematic difference – which is entirely unavoidable so long there is any vowel at all preceding the target glide – means that the significant differences in the formant values measured for [i]-glides and [i̘]-glides might arise not because the glides maintain a surface contrast in [ATR], but simply because they are affected by the [ATR] specifications of the vowels which precede them. Therefore, before concluding that underlyingly [ATR] contrasts are preserved in the course of glide formation, we should consider the possible influence that perseveratory coarticulation might have on our results.

The most plausible coarticulation-based explanation for the fact that [i̘]-glides show lower F1 and higher F2 values than [i]-glides is that while all glides are specified as [-ATR], glides which follow [+ATR] vowels are pronounced with more advanced tongue roots due to the effects of perseveratory coarticulation.[5] According to this explanation, whenever an [i̘]-glide sounds more advanced than a [i]-glide, this is simply because its tongue root position is an articulatory compromise between its own [-ATR] specification and the [+ATR] specification of the vowel preceding, while the tongue root position of the [i]-glide is purely [-ATR].

This explanation, though *a priori* plausible, runs into problems explaining the acoustic properties of glides following low vowels. As shown in (16) and (17) below, [i̘]-glides which follow [a̘] have lower F1 values and higher F2 values than [i]-glides which follow [a]. Therefore, according to the logic of the coarticulation-based explanation just described, the tongue root position of an [i̘]-glide should arise out of a compromise between its own [-ATR] target and the more advanced target of [a̘], while the tongue root position of an [i]-glide should reflect only the [-ATR] target of the glide itself. However, this conclusion is difficult to reconcile with the results of Gick et. al.'s (2006) investigations into the articulatory properties of tongue root advancement in Kinande vowels. As shown in (18), Gick et al. found that in general, higher vowels are pronounced with more advanced tongue roots than lower ones, and that this effect is so pronounced that the tongue root in [+ATR] [a̘] is actually slightly *less* advanced than the tongue root in [-ATR] [i]. This being the case, it is reasonable to assume that [-ATR] glides – which, if anything, are higher than [-ATR] vowels – are also more advanced than [a̘]. If that is so, however, it is not clear how coarticulation with the *less* advanced tongue root configuration of [a̘] should cause a [-ATR] glide to sound more advanced.

(16) a. F1 in glides after [a]/[a̘] b. F2 in glides after [a]/[a̘]

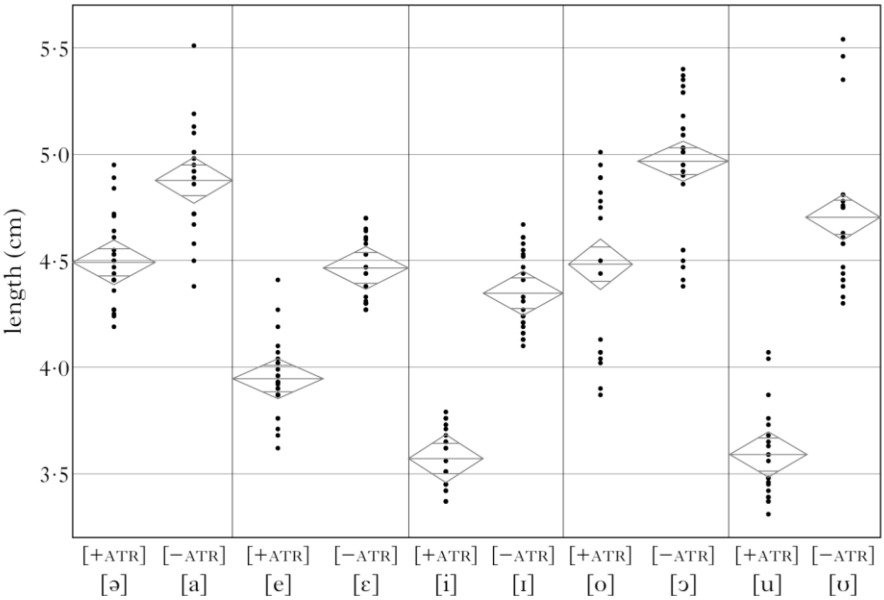


[5] An alternative explanation is that all glides are specified as [+ATR], but those which are realized after [-ATR] vowels are realized as less advanced due to coarticulation. This hypothesis is fairly implausible, however, since it requires that glides neutralize to what (in Kinande, at least) is clearly the more marked value for [ATR].

(17) Mean F1 and Mean F2 of glides derived from [i] and [ị] after [a]/[ạ]

	[i]-glides	[ị]-glides	
Mean F1 (Hz)	493	444	p = 0.07
Mean F2 (Hz)	1768	1898	p < 0.01

(18) Articulatory data from Gick et. al (2006): Univariate scatterplot of tongue-root distance from transducer for all Kinande vowels (higher values indicate a greater degree of retraction).



A more direct argument that a preserved [ATR] contrast – and not perseverative coarticulation – is responsible for the F1 and F2 differences observed between [i]-glides and [ị]-glides could be made if only the glides could be compared in contexts where they are not preceded or followed by any harmonizing vowel. However, such contexts are extremely difficult (perhaps impossible) to find in normal, grammatical speech. In a first attempt to address this problem, I elicited two imperative forms which, though entirely ungrammatical, do feature a minimal pair of glides derived from [-ATR] and [+ATR] vowels in a context where the [+ATR] vowels do not trigger harmony: ***lwana** 'quarrel each other!' (from root **-lu-**) and ***lwana** 'leak each other!' (from root **-lụ-**). The results, though still preliminary, are nevertheless quite striking. The glides are quite distinct auditorily, and their auditory distinctness is strongly reflected in their measured formant values: the glides derived from **-lụ-** have much lower F1 values than the glides derived from **-lu-** (380 Hz and 345 Hz *vs.* 516 Hz and 668 Hz), and, as expected for [+ATR] *back* vowels or glides, much lower F2 values as well (1026 Hz and 975 Hz *vs*. 1239 Hz and 1227 Hz). This result, in a context where the glides are definitely not influenced by [ATR] differences in their surrounding vowels, suggests that glides really do bear distinct [ATR] features, and do not differ solely due to the effects of coarticulation.

3. Conclusions

The results of this paper suggest strongly that glides derived from high vowels preserve their underlying [ATR] specifications, and so corroborate – and provide an acoustic explanation for – Mutaka's and Kavutirwaki's intuitions that the "ATR-ness" of a vowel can still be heard once that vowel undergoes glide formation. This fact is important not just for the analysis of Kinande, but for the study of the phonetic contrast in general: [ATR] is not, as standardly assumed, a feature that can only be realized on vowels, but one that can be realized on glides as well. Presumably, this is due to the fact that glides, like vowels, possess rich formant structures in which the acoustic cues for [ATR] can be readily perceived; it would be interesting to know, therefore, whether other sounds with rich formant structures – such as liquids, for example – might be capable of bearing surface [ATR] contrasts as well. Such questions must be left to future research.

The finding that glides in Kinande preserve their underlying [ATR] specifications also has important implications for the analysis of [ATR] harmony and for the analysis of phonological opacity: in particular, the fact that glides contrast on the surface for [ATR] means that the interaction of glide formation and [ATR] harmony is *not* opaque. Thus, as we develop and refine theories of phonological opacity, this is one interaction that we need not – and should not – account for.

Appendix: Full word list used to elicit glides

1a	omú-híni	'handle'	1b	omụ́-bị́nị	'sorcerer'
2a	omu-síngíri	'a kind of tree'	2b	obú-sịngị́rị	'funeral dance'
3a	omú-kiki	'border'	3b	omụ́-lị́kị	'rope'
4a	aká-hingi	'type of mouse'	4b	omụ́-hị́ngị	'worker'
5a	eki-bámbáli	'a tray, a big dish'	5b	omụ́-kwạ́kạ́lị	'a widow/widower'
6a	olú-bíbi	'limit of a field'	6b	omụ́-bị̀bị	'sower in a field'
7a	eki-hínzi	'cattarh'	7b	omụ́-sị́nzị	'butcher'
8a	omú-káli	'mean person'	8b	omụ́-kạlị	'woman'
9a	aka-pípi	'a ghost'	9b	ekị́-pị́pị	'a type of small bird'
10a	aka-bíhi	'(small) constipation'	10b	omụ́-lị́hị	'a root'
11a	ekí-súli	'bird w/ black feathers'	11b	ekị́-sụ́lị	'a head skin disease'
12a	omú-kúbi	'a type of sauce or soup'	12b	olụ́-kụ́bị	'orphan-hood'
13a	omú-kámbi	'sugar cane residue'	13b	olụ-thạ́mbị	'dynamite'
14a	ekí-gáni	'species of rat'	14b	ekị-hạ́nị	'type of basket'
15a	omú-táhi	'branch'	15b	omụ-rạ́hị	'thief'
16a	ekí-babi	'a leaf'	16b	obụ-gạ́bịa	'share'
17a	omu-bíri	'the human body'	17b	omụ-bị́rị	'work'
18a	ekí-suki	'bush'	18b	eyị́-sụ́kị	'a fly'
19a	eki-híndi	'piece'	19b	omụ-hị́ndị	'closer; Indian'
20a	omu-kumbi	'a type of rat'	20b	ekị́-thụmbị	'chair'
21a	omú-himbi	'leg, calf'	21b	omụ-hị́mbị	'builder'
22a	obú-tútsi	'banana alcohol'	22b	omụ-tụ́tsị	'a Tutsi person'
23a	omu-sángi	'old tattered clothing'	23b	omụ-kạngị	'a barrier'
24a	aká-sinini	'dynsentery'	24b	ekị́-tịnị́nị̂	'gums'
25a	omú-húni	'a caterpillar'	25b	omụ-hụ́nị	'silent person'
26a	omu-sási	'blood'	26b	omụ́-hạ́sị	'person who starts'
27a	omú-saki	'herbal doctor'	27b	omụ́-sạ́kị	'writer'
28a	eki-túndúli	'small hill, mound'	28b	omụ́-tụndụ́lị	'a pounder'
29a	omú-salisali	'blade, small stick'	29b	omụ́-kụmụkạlị	'female witch doctor'
30a	aka-ngírî	'a small wild pig'	30b	omụ-lị́rị	'a crying person'
31a	olú-límí	'tongue'	31b	omụ-lị́mị	'cultivater'

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