Low vowel alternations in African ATR harmony systems: an expanded typology

Sharon Rose, University of California San Diego

1. Introduction

Typological studies of ATR harmony systems across the Macro-Sudan belt of Africa have revealed a number of patterns that advance understanding of the role of vowel inventories in predicting presence and type of harmony, vowel markedness, and harmony dominance patterns (Dimmendaal 2001; Clements & Rialland 2008; Güdelmann 2010; Casali 2003, 2008, 2016, 2024; Rose 2018). Casali (2008) notes two types of ATR systems that are geographically distributed. Nilo-Saharan languages and Niger-Congo languages in East Africa (e.g. Kordofanian languages of the Nuba Mountains, Ubangi languages of Sudan and Bantu languages spoken in the eastern Democratic Republic of the Congo) have vowel systems in which ATR contrasts among high vowels are prevalent, both when there are mid vowel contrasts present and when there are not. These systems are labeled 2IU systems in Casali (2008) in recognition of the fact that there are two contrastive high vowels of each backness. In contrast, in Niger-Congo languages of West Africa, numerous languages do not have ATR contrasts among high vowels and ATR harmony is not always present. These systems are labeled 1IU, as there is no ATR contrast for high vowels. Two important generalizations are associated with these two types of vowels systems. First, the presence of high vowel contrasts (2IU) is strongly correlated with the presence of ATR harmony, whereas contrasts among mid vowels only is not (Rose 2018). Of the 207 Niger-Congo languages examined in Rose (2018) with mid vowel contrasts and no high vowel contrasts, only 40%, have ATR vowel harmony. Rolle et al (2020) further shows that this geographical division is reinforced by the dominance of vowel systems with interior (central) vowels and no ATR harmony in Central Africa, attribuable to an antagonistic relationship between interior vowels and ATR. Second, in addition to the inventory correlation with the presence of ATR harmony, Casali (2003, 2016, 2024) shows that these two inventory types also correlate with dominance patterns of ATR. 2IU systems show evidence of [+ATR] dominance, such as dominant [+ATR] affixes, preservation of [+ATR] in vowel coalescence, and allophonic [+ATR] dominance, in which unpaired vowels have a [+ATR] allophone due to [+ATR] harmony. 1IU systems rarely show these patterns and instead have patterns consistent with [-ATR] dominance.

With respect to low vowels, Casali (2003, 2016, 2024) notes that one characteristic of 2IU and [+ATR] dominance that primarily affects low vowels is *allophonic [+ATR] dominance* in which unpaired /a/ has a [+ATR] allophone due to harmony. This pattern is less likely in 1IU systems, based on his survey of 110 languages. Casali (2016) notes several further

generalizations about low vowels. First, 2IU systems can have low [+ATR] vowels, but 1IU do not appear to, although they may have mid [+ATR] central vowels. Second, if [+ATR] low vowels exist in 1IU systems, they do not behave as marked sounds. Third, there are some 1IU languages in which /a/ conditions [+ATR] harmony of mid vowels, but this does not occur with 2IU languages.

This paper builds on this work with respect to low vowels by examining the robustness of the generalizations vis à vis the larger collection of languages in the Areal Linguistic Features of Africa (ALFA) database (Rolle et al 2020) and by focusing on the participation of low vowels as *targets* of harmony. The study supports the claim that in 2IU systems, alternation of the low vowel can be with either a phonemic low or mid [+ATR] vowel or a [+ATR] allophonic alternation, but there can also be no alternation. In 2IU ATR systems, /a/ is *licensed* to alternate but whether it does alternate or not appears to be language specific and not necessarily predictable from the inventory, even in 10 vowel systems. In contrast, /a/ does not alternate in 1IU vowel systems, with only one exception. This pattern is connected to the two main generalizations mentioned above with respect to high vowel contrasts: they predict whether a language will have ATR harmony or not (Rose 2018) and they favor [+ATR] dominance (Casali 2003, 2016, 2024). As Casali explains, if [-ATR] is dominant in 1IU systems, and /a/ is the sole low [-ATR] vowel, then there is no reason for it to alternate. In addition to supporting the prior generalizations, the study shows that Casali's generalization that while 1IU vowel systems do not appear to have low [+ATR] central vowels, they may have mid [+ATR] central vowels, turns out to be a far stricter generalization in two ways. If a 1IU language has a mid [+ATR] central vowel, it does not function as the alternant of /a/. Only one IU language in the database, Wolof, is reported to have a [+ATR] central vowel with which /a/ alternates. The presence of a [+ATR] alternating counterpart to /a/, either a phonemic counterpart or an allophone, is therefore very strongly tied to the presence of a high vowel ATR contrast.

2. Typology database

This paper employs data drawn from the *Areal Linguistic Features of Africa (ALFA)* database of 681 African languages (Rolle et al 2020). The languages featured in the database are spoken across the Macro-Sudanic belt, namely West and Central Africa, Sudan and East Africa. There is no attempt to balance the sample in the database genetically; the goal is to include data from as many languages as possible. I have made a few reclassifications of languages based on updated material or further investigation. These will be pointed out where relevant. There are

357[1] languages in the database that are reported to have some kind of vowel harmony. This could be cross-height vowel harmony in which both high and mid vowels participate, labeled 'complete harmony' in Rolle et al (2020), or it could be 'incomplete harmony' with restrictions on combinations of mid vowels, but not cross height harmony where high vowels are also targets of harmonic alternations. This type of 'incomplete' harmony may be static harmony in roots or dynamic systems with alternations. Standard Yoruba, for example, would be an example of an incomplete harmony system. There are also languages that ALFA classifies as 'trace' ATR harmony, of which there are only vestiges of harmony. In examining the inventories, I focus on short oral vowels, setting aside the nasalized and long counterparts, and I also set aside the trace languages and the static languages in this survey as these do not have clear alternations. This leaves 300 languages examined with dynamic ATR harmony. The goal is to assess the participation of the low vowel and its alternation with central vowels in the harmony system. We begin with the large vowel inventories and progress to smaller ones where there are gaps in the inventory.

3. 2IU-2EO vowel inventories

3.1 2IU-2EO vowel inventories with ten vowels

The prototypical symmetric vowel system is one in which there are 10 vowels, five [+ATR] vowels and five [-ATR] vowels. The transcriptions for the [+ATR] low/mid central vowel vary between [ə] [ɜ] [æ] [ɐ] and [ʌ].[2] Its acoustic realization is often more in the range of the mid vowels based on its F1. Casali (2016) makes a distinction between low vs. mid [+ATR] counterparts of /a/, using the IPA [ạ] to reference the low [+ATR] vowel. In this paper, we do not make this distinction since it requires a thorough investigation of both the phonetics and

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[1] This figure is adjusted. I removed three languages from the harmony list and classified two of them as 'no harmony' and one as 'trace' harmony. The first is Tira, which was classified as 'complete harmony', but our own current research on the language shows that there is a 7 vowel inventory (i e ɛ a ɔ o u) and no vowel harmony. The second is Laal, an isolate language of Chad, which has 12 vowels, with both front round and central vowels. Laal is classified as having mid ATR harmony in ALFA, but according to Lionnet (2016), it has low harmony, not ATR harmony. These numbers reflect that change. Finally, Belanda Bor has vowel height alternations (that disregard ATR), and one lexicalized singulative suffix that alternates for ATR, but otherwise does not show ATR (van Heyking 2003). This is therefore reclassified as 'trace'

[2] Transcriptions often vary to indicate the low vowel. We will use /a/ to indicate a low [-ATR] vowel.

phonology of each language to make a determination as to whether the [+ATR] central vowel should be classified as low or mid.

(1)   [+ATR]   [-ATR]

                     i   u   ɪ   ʊ

                    e   o   ɛ   ɔ

                        ə   a

There are 59 languages in the database with ten contrastive vowels, all of which have the symmetric ATR system above with 'complete' cross-height ATR harmony. These languages are further subdivided by phyla as follows.[3]

Phylum: Language (Sub-group)	# of languages
Afro-Asiatic: Somali (Cushitic-1); Hamer-Banna (Omotic-1)	2
Nilo-Saharan: Nandi, Pari, Bari, Keiyo, Luwo, Marweeta (Nilotic-6); Kanembu (Saharan-1); Tennet (Surmic-1); Moru (Central Sudanic-1); Kanga, Tese, Tulishi (Other N-S-3)	12
Niger-Congo: Bolgo (Adamawa-1); Bainouk-Gunyaamolo, Bandial, Bayot, Lehar, Gubeeher-Gufangor-Gubelor, Jola-Fonyi, Jola-Kasa, Karon, Kuwaataay, Ndut, Noon, Palor (Atlantic-12), Nomaande, Yambeta (Bantu-2), Koromfe, Dagbani, Turka (Central Gur-3), Agoi Odual, Ogbronuagum (Delta Cross-3), Bondum Dom Dogon (Dogon-1), Degema (Edoid-1), Bissa (Eastern Mande-1), Igede (Idomoid-1), Hone (Jukunoid-1), Katla (Kordofanian-1), Yukuben (Platoid-1), Anyi, Nzema, Abron, Gonja (PotouTano-4), Deg, Kasem, Lobi, Lyele, Delo Vagla (Southern Gur-6), Belanda Viri, Nzakara (Ubangi-2), Ikposo, Akebu, Sekpele (Other Kwa-3)	45
Total	59

Table 1: Languages with ten vowels and complete ATR harmony

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[3] ALFA lists Shilluk as having vowel harmony, but Remijsen et al (2011) reports there is no harmony and only morphological alternations for ATR. We therefore removed this language from the list of complete harmony languages.

There is a dominance of Niger-Congo languages in Table 1, but Niger-Congo languages are in general more numerous and have more representation in the database.

In a 10 vowel system, it is expected that /a/ will alternate with its [+ATR] counterpart /ə/ or /ʌ/, as occurs in languages like Diola-Fogny (Sapir 1965, Casali 2018) or Bari (Hall & Yokwe 1981, Hout 2019). However, the fact that a [+ATR] central counterpart to /a/ exists in the vowel system does not always mean that /a/ *alternates* with it. For example, in Päri (Andersen 1989), /ʌ/ can trigger [+ATR] harmony, but /a/ in affixes does not alternate with /ʌ/ and remains neutral. The forms *á-kéel-ò́* 'we (incl) shot it' and *á-rúʊd-ɔ̀́* 'we (incl) ground it' show alternation of -o/-ɔ person suffixes, but but *á-kèel-á* 'I shot it' and *á-rʊ̀ʊd́-à* 'I ground it' show no alternation for -a (p. 11-12). Similar patterns are noted in Akposso (Anderson 1999) and Sekpele (Delalorm 2009). In ALFA, 13/59 languages with the 10 vowel system are listed as having an central mid phonemic vowel which is not a [+ATR] counterpart to /a/. Two languages have a low /ɑ/ with which /a/ alternates, and the rest (44) have a mid central vowel /ʌ/ or /ə/ with which it alternates. This demonstrates that there is a distinction between the target and trigger behaviour of central vowels. Although a 10 vowel inventory may license ATR harmony and the [+ATR] low/mid central vowel may trigger harmony, alternation for [ATR] between the low [-ATR] vowel and its central [+ATR] phonemic counterpart is not required. Such patterning relates to the markedness of low [+ATR] vowels expressed with the markedness constraint *LOW/+ATR (Archangeli & Pulleyblank 1994), even in languages in which there is a potential counterpart in the inventory with which /a/ could alternate.[4] See also Ozburn (2022) who explores the disconnect between inventory and low vowel behaviour in Mayak and Kurmuk and its theoretical implications. This pattern also relates to the antagonistic relationship between ATR and interior (central) vowels reported in Rolle et al (2020).

3.2 2IU-2EO vowel inventories with more than ten vowels

There are five languages in the ALFA database that have systems larger than 10 vowels with complete ATR harmony. These all include additional central vowels. While some of these central vowels do alternate with /a/, others do not.

Tima is a Niger-Congo language spoken in Sudan with a symmetric 12 vowel inventory. All vowels fully participate in harmony (Bashir 2010, 2013, Tabain et al 2024). The low vowel /a/ alternates with /ʌ/ and the mid central vowel /ə/ alternates with /ɨ/, both of which are phonemic vowels in the language:

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[4] This assumes that such vowels are phonologically [+low]. If they are [-low, -high], then the constraint would need to be adapted to disfavor mid central +ATR vowels as well: *[-high, -front, -back, +ATR].

(2)   Tima vowel inventory

[+ATR]	[-ATR]
i ɨ u	ɪ ə ʊ
e ʌ o	ɛ a ɔ

Bété and Godié, two Eastern Kru languages of Côte d'Ivoire, are also reported to have 12 vowels. Nevertheless, their systems are not symmetric for [ATR] like Tima. Zogba (2019) reports that Daloa Bété has 12 vowels, four of which are central. Three of the central vowels are [+ATR] while the low vowel /a/ is [-ATR], and yet, it does not alternate. The low vowel thus has no harmonic counterpart, and is a neutral vowel that can cooccur with both [+ATR] and [-ATR] vowels. While Marchese (1978:50) notes 12 oral vowels for Godié, Zogba (2019) reports that Godié has 13 vowels. The four higher central vowels are paired for ATR, but /a/ is an unpaired non-harmonic vowel.

Anii (Morton 2012) and Lama (Ourso 1989) each have 11 vowels. Anii, a Ghana-Togo-Mountain language, spoken in Benin and Togo, has the standard 10 vowel inventory with an additional high central vowel /ɨ/: /i ɪ ɨ e ɛ ə a ɔ o ʊ u/. The /ɨ/ is [-ATR] and phonemic, cooccurs only with [-ATR] vowels and has no [+ATR] counterpart. Morton does not report it alternating due to harmony. The Lama inventory is /i ɪ e ɛ a ə ɜ ɔ o ʊ u/ (Ourso 1989).[5] There are ATR contrasts among the high central vowels [+ATR] /ə/ and [-ATR] /ɜ/, but not for the low vowels. In vowel harmony, allophonic [ʌ] is the counterpart to /a/.

In conclusion, the languages with vowel inventories larger than ten have the symmetrical 10 vowel system with additional central vowels, although whether and how the central vowels participate in vowel harmony varies. Underlining indicates alternating pairs.

Phylum	Language	# of vowels	[-ATR]	[+ATR]
Niger-Congo	Tima	12	a̠ ə̠	ʌ ɨ̠
	Bété	12	a	ɨ ʉ ə
	Godié	13	a ʌ̠ ʉ̠	ə̠ ɨ̠
	Anii	11	a̠ ɨ	ə̠
	Lama	11	a̠ ə̠	[ʌ] ɨ̠
Total:	5			

Table 2: Languages with >10 vowels and ATR harmony

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[5] Ourso (1989) uses the symbols ɨ and ʉ for the high [-ATR] vowels.

3.3   9 vowel 2IU-2EO inventories with no low-vowel contrasts

The 9 vowel 2IU-2EO inventories are by far the most frequent pattern, and they cross-cut both Niger-Congo and Nilo-Saharan languages. There is also one Afro-Asiatic language. They have complete harmony and the following vowel system in which the /a/ is classified as a [-ATR] vowel.

(3)   [+ATR]   [-ATR]

       i   u   ɪ   ʊ

       e   o   ɛ   ɔ

                               a

In a nine-vowel system in which there is no harmonic counterpart to [-ATR] /a/, the participation of /a/ as a target of harmony varies. First, /a/ may alternate with another existing non-central [+ATR] phoneme, such as /e/ or /o/, as in Lika where /a/ → [o] (Kutsch Lojenga 2008) or Avatime where /a/ → [e] (van Putten 2014, Lehman 2024). Second, harmony may produce a [+ATR] allophone, such as [a̩] or [ə] as in Kinande (Gick et al 2006). The third option is for the /a/ to be neutral to ATR harmony and not alternate. When this occurs, it may be either transparent, as in Budu (Kutsch Lojenga 1994), or opaque, as in Nkami (Akanlig-Pare & Asante 2016). Which option a language exhibits does not seem to be predictable from the inventory of vowels. These languages all have the same nine vowel phonemic inventory.

Phylum: Language (Sub-group)	# of languages
Afro-Asiatic: Tangale (Chadic)	1
Nilo-Saharan: Toposa, Otuho, Lopit, Teso, Karamojong, Masai, Turkana (Nilotic-7); Aringa, Bongo, Jur Modo, Mangbetu, Olu'bo, Ngiti, 'Bëlï, Keliko, Ma'di, Morokodo (C. Sudanic-10); Kacipo-Balesi, Didinga, Narim (Surmic-3); Katcha, Ik, Miri, Tagle, Temein (Other N-S-5)	25
Niger-Congo: Kulaal (Gula Iro), Waja (Adamawa-2); Balanta-Ganja, Gusiilay (Atlantic-2); Bila, Budu, Lika, Vanuma, Nugunu, Elip, Yangben, Mbule, Mmaala, Nubaca Bantu-10); Dagara, Dagaare, Buli, Kaansa, Konni, Kusaal, Farefare, Southern Birifor, Tem (Central Gur-9); Oka-Akoko Yoruba (Defoid-1); Abua (Delta-Cross-1)[6]; Engenni, Okpe, Epie, Eruwa, Isoko, Urhobo, Uvbie, Ukaan (Edoid-8); Neyo, Lakota Dida (Eastern Kru-2);[7] Yaoure, Guro (Eastern Mande-2); Ika, Ekpeye Igbo, Ikwere, Oka Igbo, Ukwuani, Izi (Igboid-6); Ibani, Izon, Kalabari, Southeast Ijo, Kirike, Biseni, Okodia, Oruma (Ijoid-8); Gade, Ebira (Nupoid-2); Bouna Kulango, Bondoukou Kulango, Loma, Teen (Other Gur-4); Aizi (Other Kru-1), Abe, Abidji, Avatime, Nyangbo (Other Kwa-4); Nkonya, Tafi, Ega, Abure, Ahanta, Akan, Awutu, Beti, Chumburung, Foodo, Gikyode, Ginyanga, Krache, Larteh, Nawuri, Nkami (PotouTano-16); Dazaga (Saharan-1); Nuni, Dogose, Kabiye, Kalamse, Paasaal, Tampulma, Western Sisaala (Southern Gur-7); We Southern, (Western Kru-1)	87
Total	113

Table 3: Languages with 9 vowels and 'complete' ATR harmony

The ALFA database notes an central [+ATR] allophonic alternant of /a/ in 14 languages with the 9 vowel 2IU-2EO system: Gusiilay, Nubaca, Engenni, Ukaan, Gade, Nkonya, Nuni, Aringa, Bongo, Keliko, Ma'di, Morokodo, Temein, and Akan. However, it does not report the [e] or [o] alternants of /a/ which are attested in languages such as Budu, Lika, Kɔnni, or the Mbam languages (see below). Of course, it may also be the case that allophony of /a/ is underreported

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[6] This language is listed with /i e ɛ a o ɔ u ʊ/ in ALFA, but Kari & Joshua (2011) report a symmetrical 10 vowel system.

[7] Lakota Dida (Eastern Kru) was classified in ALFA as having 7 vowels. However, it appears to actually hvave 9 vowels and is added to this list (Guéhoun 1993, Marchese 2019).

or may require acoustic analysis to determine, as noted in Gick et al (1996) for Kinande, a 2IU 7 vowel system. Moreover, sources do not always indicate allophonic alternants, or they may not explicitly provide this information, so it is not easy to provide figures on the various possibilities. Nevertheless, having a [+ATR] central allophone of /a/ is noted in 12% of the 9 vowel 2IU-2EO systems in ALFA.

3.4   2IU-2EO asymmetric vowel inventories

There are a small number of languages with vowel systems that are classified as 2IU-2EO, but which have fewer than 9 vowels as they have a gap among the front vowels. Despite these missing vowels, their harmony patterns are cross-height and like those of the 2IU-2EO 9 and 10 vowel systems.

There are four languages with 8 vowels in which there are contrasts in both the high and the mid vowels among back vowels, but there are some front vowel contrasts missing. Some are lacking the high /ɪ/ some the mid /ɛ/, and one language lacks both /e/ and /ɛ/, but has an central vowel.

Language/Sub-group	Vowel system	# of languages
Niger-Congo		
Tunen (Bantu)	8: i ɪ ə̱ a̱ o ɔ u ʊ	1
Onitsha Igbo (Igboid)	8: i ɪ e a o ɔ u ʊ	1
Okpamheri (Edoid)	8: i e ɛ a o ɔ u ʊ	1
Iceve-Maci (Bantoid)	8: i e̱ ɨ a̱ o ɔ u ʊ	1
Total		**4**

Table 4: 2IU-2EO languages with missing vowels but 'complete' ATR harmony

Tunen has a [+ATR] phonemic counterpart /ə/ to the /a/, but is missing [e] and [ɛ]. The other languages do not have a contrast with the low /a/, and are missing one or more of the front [-ATR] vowels. In Iceve-Maci, the vowel /ɨ/ is [-ATR] and not an ATR counterpart of /a/. /a/ alternates for ATR with [e] or an allophonic [ə]. Meanwhile, /i/ alternates with allophonic [ɪ] (Cox 2013), while /ɨ/ can become [i].

It is worthwhile to look closer at the vowel inventories of the nine Mbam langauges related to Tunen analyzed in Boyd (2015). Four languages have the standard 9 vowel inventory but no low vowel contrasts. Four languages, including Tunen, lack /ɪ/ and /ɛ/ but have a

[+ATR] /ə/. Two others are missing /ɪ ɛ/ and /ə/. Finally, Tuki is missing /ɪ/ /ɛ/ and the back /ɔ/, but has the [+ATR] /ə/.

# of vowels	Vowel inventory	Language
9	i ɪ e̲ ɛ a̲ o ɔ u ʊ	Mmala
	i ɪ e̲ ɛ a̲ o ɔ u ʊ	Yangben
	i ɪ e̲ ɛ a̲ o ɔ u ʊ	Mbure
	i ɪ e ɛ [ɜ]a̲ o ɔ u ʊ	Baca
8	i e ə̲ a̲ o ɔ u ʊ	Nen (Tunen)
	i e ə̲ a̲ o ɔ u ʊ	Maande
	i e ə̲ a̲ o ɔ u ʊ	Yambeta
7	i e ə̲ a̲ ɔ u ʊ	Tuki
	i e̲ a̲ o ɔ u ʊ	Gunu
	i e̲ a̲ o ɔ u ʊ	Elip

Table 5: 2IU-2EO Mbam languages (Boyd 2015)

These inventories are interesting for what they reveal about symmetry. As previously noted, 9 vowel 2IU-2EO inventories lack a [+ATR] low/mid central vowel. However, for 8 and 7 vowel inventories, there can be gaps both with and without central contrasts with /a/. In the languages with a phonemic /ə/, this vowel is the alternant of /a/. However, for five of languages without /ə/, alternation is with /e/; only one has a [+ATR] allophone [ɜ]. All ten Mbam languages show a [+ATR] alternation with /a/.

In conclusion, the following Table shows the total number of languages with 2IU-2EO systems. As mentioned, in these systems /a/ has the potential to alternate for [+ATR] with an central vowel, either with a phoneme or an allophone, but it is not required to. It is also possible for it to alternate with a [+ATR] peripheral mid vowel such as [e] or [o] in the 8 or 9 vowel systems (not indicated in the summary Table). There does not seem to be distinct behaviour between 2IU-2EO Niger-Congo and Nilo-Saharan languages with respect to the behaviour of the low vowel. These four categories are 1) /a/ alternates with a +ATR phonemic vowel (/a/ ~ /ə/); 2) /a/ alternates with a +ATR allophone (/a/ ~ [ə]); 3) /a/ does not alternate and there is no other central vowel; 4) /a/ does not alternate and there is another central vowel.

2IU-2EO	/a/ ~ /ə/	/a/ ~ [ə]	/a/	/a/ /ə/	# of languages
10	46	0	0	13	59
11/12	2	1	0	2	5
9	0	14	99	0	113
8	1	0	2	1	4
Total	49	15	101	16	181

Table 6: Summary of languages with 2IU-2EO vowel systems

4.   2IU-1EO 7 and 8 vowel inventories

As stated in the introduction, there are two kinds of 7 vowel inventories, those that have an ATR contrast for high vowels but no contrasts for mid vowels (2IU-1EO), and those that have no contrasts for high vowels, but contrasts for mid vowels (1IU-2EO). The 2IU-1EO system is given below:

(4)   2IU-1EO

        i   u

        ɪ   ʊ

        ɛ   ɔ
            a

The 2IU-1EO type of language often has [+ATR] mid allophones and can also contain an central vowel. In some languages, this is a phonemic [+ATR] counterpart to [-ATR] /a/, but in others it is an additional neutral vowel or a [-ATR] central vowel that may in turn have its own [+ATR] allophones. Like for 9 vowel 2IU-2EO languages, [+ATR] allophones of the low vowel can be found in some of the 2IU-1EO languages, too.

4.1   2IU-1EO inventories with one central vowel /a/

Languages that have a contrast among high vowels but not mid vowels are found more commonly among Nilo-Saharan languages (Casali 2008, Rose 2018), as well as in the Niger-Congo languages that neighbor Nilo-Saharan languages in East Africa. These languages also exhibit cross-height harmony.

Those that have seven vowels and no contrast for the central low /a/ are reported below. These all exhibit 'complete' or cross-height harmony. This is so because ATR harmony creates the allophones [e] and/or [o] as counterparts of /ɛ/ and /ɔ/. The five Bantu languages are Amba, Talinga-Bwisi (Democractic Republic of the Congo) Gungu (Uganda), Malila and Langi (Tanzania), all Eastern Bantu languages. All of the langauges in Table 7 have [e] and [o], except for Krongo, which is missing the [o] allophone. Four of the languages also have an allophonic [+ATR] counterpart of /a/.

Phylum/Language/Sub-group	[+ATR] allophone of /a/	# of languages
Niger-Congo: Amba, Talinga-Bwisi, Gungu, Malila, Langi (Bantu-5)	no	5
Niger-Congo: Nande (Bantu-1)	yes	1
Nilo-Saharan: Lugbara, Mvuba, Mangubutu, Bendi, Lese (C. Sudanic-5), Kakwa (Nilotic), Opuuo, Uyncu, Krongo (Other N-S-3)	no	8
Nilo-Saharan: Terego Lugbara (C. Sudanic), Beria (Saharan), Komo (Other N-S)	yes	3[8]
Total		17

Table 7: Languages with 7 vowels 2IU-1EO and 'complete' ATR harmony

Thus, while it is a common pattern to produce mid vowel allophones [e o] with such vowel systems, the [+ATR] allophone of /a/ seems to be optional, as it is with 9 vowel systems.

4.2   2IU-1EO 7 and 8 vowel inventories with more than one central vowel

Some languages have contrasts among high vowels and an additional phonemic central vowel. In the following languages, the central vowel /ə/ is the [+ATR] counterpart to /a/, and it alternates with it.

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[8] Dazaga (Saharan) is an ambiguous case. One could consider it a 7 vowel system /i ɪ ɛ a ɔ ʊ u/ with allophonic [e] and [o], like the other Saharan language, Beria. These vowels are derived via ATR harmony. However, Walters (2015) notes words that contain [e] and [o] with no other vowels, suggesting that they have become phonemic. ALFA lists them as marginal phonemes, so I have classified this as a 9 vowel system /i ɪ e ɛ a ɔ o ʊ u/.

Phylum	Language (Sub-group)	Vowel system	# of languages
Niger-Congo	Laru (Other N-C-1),	8: i ɪ ɛ ə a ɔ u ʊ	1
	Kuche (Platoid-1)	8: i ɪ ɛ ə a ɔ u ʊ	1
Nilo-Saharan	Fur (Other N-S-1),	8: i ɪ ɛ ə a ɔ u ʊ	1
	Mundari (Nilotic)	8: i ɪ [e] ɛ ə a [o] ɔ u ʊ	1
	Burun (Nilotic)	8: i ɪ [e] ɛ ə a [o] ɔ u ʊ	1
	Avokaya (C. Sudanic)	7: i ɪ ɛ ə a ɔ u	1
Total			6

Table 8: Languages with 7 or 8 vowels 2IU-1EO and [+ATR] contrast among central vowels

In Mundari and Burun, the vowel system has 8 vowels with mid vowel allophones [e] and [o] produced via ATR harmony, thereby producing a symmetrical 10 vowel ATR system via harmony. In Laru, the mid vowels /ɛ/ and /ɔ/ do not have [e o] allophones, but alternate with the high vowels /i/ and /u/ (Kuku 2012). The same is the case for Fur in lexical processes, but in post-lexical harmony, [e] and [o] are the harmonic counterparts (Kutsch Lojenga 2012). Kuche is a Platoid language spoken in Nigeria. It has an 8 vowel inventory /i ɪ u ʊ ɛ ɔ ə a/ so has a an additional central vowel /ə/ which alternates with /a/ for [ATR], but the mid vowels lack [+ATR] allophones (Wilson 1996). However, the [-ATR] mid vowels occur in roots rather than affixes; therefore, there is no opportunity for such allophones to arise via alternations as there are no dominant affixes. Avokaya is a Central Sudanic language that has an asymmetric 7 vowel 2IU-1EO inventory rather than 8 vowels as it is missing the /ʊ/. But it has a low vowel phonemic contrast: /i ɪ ɛ ə a ɔ u/, and /a/ alternates with /ə/ in ATR vowel harmony. While /ɛ/ has an allophonic counterpart [e], the back round /ɔ/ alternates with /u/ (Callinan 1981), as in Fur and Laru.

In other languages, the non-high central vowel is either neutral or is a higher [-ATR] vowel with its own [+ATR] allophone. Acheron, Dagik and Tocho are Talodi (Kordofanian) languages spoken in Sudan. Their vowel inventories consist of eight phonemic vowels /i ɪ ɛ a ə ɔ ʊ u/ with allophonic [+ATR] counterparts of all the non-high vowels: [e ɜ ə o] derived via harmony (Alaki & Norton 2013; Norton 2013; Vanderelst 2016). Finally, In Baka the vowel system is /i ɪ ɛ ɨ a ɔ ʊ u/ with [+ATR] allophones [e ə o] of /ɛ a ɔ/. The /ɨ/ is a neutral vowel. In all these languages, therefore, the low vowel /a/ has either a phonemic counterpart with which it alternates, or a [+ATR] conditioned allophone.

Phylum	Language (Sub-group)	Vowel system	# of languages
Niger-Congo	Acheron (Other N-C)	8: i ɪ [e] ɛ [ə] ə [ɜ] a [o] ɔ u ʊ	1
	Dagik (Other N-C)	8: i ɪ [e] ɛ [ə] ə [ɜ] a [o] ɔ u ʊ	1
	Tocho (Other N-C)	8: i ɪ [e] ɛ [ə] ə [ɜ] a [o] ɔ u ʊ	1
Nilo-Saharan	Baka (C.Sudanic)	8: i ɪ [e] ɛ ɨ [ə] a [o] ɔ u ʊ	1
Total			4

Table 9: Languages with 8 vowels 2IU-1EO and 'complete' ATR harmony with no ATR contrast among central vowels

In conclusion, in all the 2IU-1EO languages, there are ATR alternations among high vowels and non-high vowels. These alternations are typically mid vowels /ɛ ɔ/ → [e o], but they can also be among low vowels, with /a/ alternating with its [+ATR] phonemic counterpart /ə/, or /a/ producing a non-phonemic allophone [ə]. As with the 9 vowel 2IU systems, a high vowel contrast licenses ATR alternations among non-high vowels. Among the languages with a single low central vowel /a/, only four have a [+ATR] allophone (Baka, Terego Lugbara, Beria and Komo), so whether the low vowel alternates or not appears to be language-specific. Nevertheless, in all ten of the languages with two central vowels, /a/ alternates in harmony. This means that in 15 of these languages, there is an /a/ alternation. Note that all the Niger-Congo languages (except one) with these systems are spoken in the Nuba Mountains of Sudan or in East Africa, so this is an Eastern African tendency.

2IU-IEO	/a/ ~ /ə/	/a/ ~ [ə]	/a/	/a/ /ə/	# of languages
7	1	4	13	0	18
8	5	4	0	0	10
Total	6	8	13	0	27

Table 10: Summary of languages with 2IU-1EO vowel systems

5.   1IU-2EO vowel inventories

Languages that have ATR contrasts among mid vowels but not high vowels (1IU-2EO) are found in many West African Niger-Congo languages, and about 40% of them have ATR vowel harmony (Rose 2018). In the ALFA database, vowel systems are coded for whether they

exhibit alternations between phonemes for mid vowel ATR harmony, which Rolle et al (2020) label 'incomplete harmony' because such systems do not involve high vowels. This type of harmony is widespread with 1IU-2EO languages. The typical 7 vowel system is as follows:

(5)   1IU-2EO

    i   u

    e   o

    ɛ   ɔ

        a

7.1   1IU-2EO vowel inventories with no low vowel contrast

Eighty-eight[9] languages show incomplete harmony where high vowels do not alternate. Of these, the majority (80) have a 7 vowel system /i e ɛ a o ɔ u/. In such systems, the high vowels are [+ATR] and the low vowel is usually [-ATR]. The vowels without counterparts can trigger harmony, but in all cases except one do not alternate themselves. As expected, based on prior typological surveys, these type of vowel systems are primarily Niger-Congo.

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[9] I reclassified the language Teke (Eboo-Nzikou), which is classified as having mid vowel harmony in ALFA, because its vowel system seems to have changed from a seven vowel system with high vowel contrasts to a nine vowel system with /e o/ phonemes, according to the source (Raharimanantsoa 2012). It is listed in ALFA without the mid vowel phonemes.

15

Phylum/Language (Sub-group)	# of languages
Afro-Asiatic: Dangaleat (Chadic)	1
Niger-Congo: Kare, Kuo, Doyayo (Adamawa-3); Wumboko-Bubia, Poke, Ligenza, Lobala, Mituku, Dengese, Ombo, Mongo, Kele, Ngombe, Ntomba, Bangi, Likuba, Mbosi, Bolia, Lingala, Ikoma-Nata-Isenye, Dibole, Mokpwe (Bantu-18); Ditammari, Central Gur-1), Standard Yoruba, Ife (Defoid-2); Eleme, Gokana (Delta Cross-2); Tebul Ure, Penange, Bunoge Dogon, Ben Tey, Nanga, Jamsay Dogon, Donno So, Tommo So (Dogon-8); Boko, Mano (Eastern Mande-2); Northwest Gbaya, Gbeya, Bokoto, Bofi, Bangando-Ngombe, Ngbaka, Manza (Gbaya-6); Yala, Agatu, Idoma, Etulo (Idomoid-4), Gbiri-Niragu (Kainji-1), Tiefo (Other Gur-1); Kuwaa (Other Kru-1); Siwu, Selee, Tuwuli, Igo, Adioukrou (Other Kwa-5), Oko-EniOsayen (Other NC-1), Lijili, Eloyi (Platoid-2); Krobu, Anufo (PotouTano-2); Gola (SAtlantic-1); Cebaara Senoufo (Senoufo-1), Tondi Songway Kiini, Dendi (Songhai-2), Gbayi, Ngbaka Ma'bo, Monzombo, GbanziriUbangi (4); Dewoin, Bassa (WKru-2), Dzuungoo, Bambara, Zialo, Seeku, Dyula, Eastern Maninkakan, Loma (WMande-7)	75
Nilo-Saharan: Furu (Central Sudanic-1); Tondi Songway Kiini and Dendi (Songhai-2)	3
Other : Principense (Creole-1)	1
Total	80

Table 11: Languages with 7 vowels 1IU-2EO and 'incomplete' ATR harmony

These languages do not generally have allophones of the high vowels created through ATR vowel harmony. Only three languages are reported to exhibit 'complete' harmony because they have allophones of the high vowels: i [ɪ] e ɛ a ɔ o ɛ u [ʊ]; two of them are Yoruba varieties.

Phylum/Language (Sub-group)	# of languages
Niger-Congo: Ijesa Yoruba; Ekiti-Irun-Ifaki Yoruba (Defoid-2), Avikam (OtherKwa-1)	3

Table 12: Languages with 7 vowels 1IU-2EO and 'complete' ATR harmony

There is no inventory in the database of 'complete' cross-height harmony with a 1IU-2EO system and an additional low vowel contrast: */i e ɛ ə a ɔ o u/. There are also no languages

among both 1IU-2EO groups that are listed in ALFA as having [+ATR] central counterparts of /a/. Casali (2016) noted this pattern with his database of 110 languages, and it is further confirmed here with the larger dataset.

7.2   Other 1IU-2EO vowel inventories

In addition to the standard 7 vowel systems, there are a small number of languages that lack one of the peripheral mid vowels, either /ɛ/ or /ɔ/, but have a central vowel /ə/ or /ʌ/. In these languages, this central vowel does not pattern as the [+ATR] alternant to /a/. There are four other languages with 8 vowel systems with a central vowel /ə/ in addition to the low vowel /a/.[10] In Lokaa, /a/ does not alternate with /ə/. Guinean Kpelle is missing the /e/ and has a nasal high vowel /ĩ/, but has three central vowels. I was not able to consult the source for this language to determine the harmony pattern of these central vowels, nor was I able to do so for Mbandja, but they are not noted as alternants of /a/. In Wolof, /ə/ does function as the [+ATR] alternant of /a/.

Phylum	Language (Sub-group)	Vowel system	# of languages
Niger-Congo	Izora (Kainji)	7: i e ə a o ɔ u	1
	Ibibio (Delta Cross)	7: i e ʌ a o ɔ u	1
	Wolof (Atlantic)	8: i e ɛ ə a o ɔ u	1
	Tiba (Bantoid)	9: i e ɛ a o ɔ u y ø	1
	Mbandja (Ubangi)	9: i e ɛ ɨ ə a ɔ o u	1
	Lokaa (Delta Cross)	8: i e ɛ ə a o ɔ u	1
	Guinean Kpelle (Mande)	8: ĩ ɛ ɨ ə a o ɔ u	1
Nilo-Saharan	Kibet (Mabaan)	7: i e ɛ ə a o u	1
Total			8

Table 13: Languages with 7 or 8 vowels 1IU-2EO and two central vowels – 'incomplete' ATR harmony

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[10] Etulo is listed with the vowels /i e ɛ ə a ɔ o u/ in ALFA based on Williamson (1973), but Eme & Okoye (2016) report /i e ɛ a ɔ o u/ with mid vowel alternations and /a/ as a neutral vowel. I therefore included this language in the 7IU-2EO list. ALFA also lists Nyong as a language with a mid central vowel and incomplete vowel harmony. However, the source, Kouonang Nganmou (1983) does not mention vowel harmony or vowel assimilation. The one central vowel is phonemic but also an alternant of /i/. Due to the uncertainty of whether the language has harmony or not, I do not include it in the database of languages with harmony.

Casali (2016) reports that these kind of 8 vowel 1IU systems with a [+ATR] mid central counterpart to the low [-ATR] vowel /a/ are well attested, citing Wolof (Ka 1988, Pulleyblank 1996), Akoose (Hedinger & Hedinger 1977), and Likpe (Lomotey 2009, Ring 2003). However, Akoose is listed in ALFA as not having [+ATR] vowel harmony and a consultation of Hedinger & Hedinger (1977) appears to confirm that. There is no mention of vowel harmony or affix alternations, and there are combinations of [e] and [ɛ] and [a] and [ə] within the word. Delalorm (2009) reports that Likpe (referred to as Sekpele) is a 10 vowel system /i ɪ e ɛ ə a ɔ o ʊ u/ where /a/ is neutral and does not alternate with /ə/ (see also discussion in Casali 2016). Nevertheless, /ə/ can trigger [+ATR] vowel harmony when in roots in Sekpele. This pattern is similar to the 10 vowel 2IU-2EO system of Akposso in which the [+ATR] ə is *not* the counterpart to /a/ (Anderson 1999). Instead, /a/ alternates with [e]. Wolof is therefore the only representatives of an 8 vowel 1IU-2EO system with a [+ATR] central vowel with which /a/ alternates.

Casali (2016) further reports the generalization that 2IU systems can have low [+ATR] vowels, but 1IU do not appear to, although they may have mid [+ATR] central vowels. However, among the languages he cites with these vowels, either the language does not have vowel harmony, or the mid [+ATR] vowel is not the alternating counterpart to /a/. 1IU systems in which there are any [+ATR] alternants of /a/ are not in fact well attested, but actually are quite rare indeed. Atlantic languages vary widely in terms of their vowel systems and harmony patterns. In the ALFA database, of the 30 Atlantic languages listed, 16 languages have complete ATR harmony; only Gola (7 1IU-2EO) and Wolof (8 1IU-2EO) have incomplete harmony and have no contrast among high vowels. The rest have static harmony (1) or no vowel harmony (13). Wolof thus appears to be an outlier both within the Atlantic languages, and also among all 1IU-2EO languages.

1IU-2EO	/a/ ~ /ə/	/a/ ~ [ə]	/a/	/a/ /ə/	# of languages
7	0	0	83	3	86
8	1	0	0	2	3
9	0	0	1	1	2
Total	1	0	84	6	91

Table 14: Summary of languages with 1IU-2EO vowel systems

Conclusion

The following Table summarizes the patterns of all the different vowel systems.

Vowels	/a/ ~ /ə/	/a/ ~ [ə]	/a/	/a/ /ə/	# of languages
2IU-2EO					
11/12	2	1	0	2	5
10	46	0	0	13	59
9	0	14	99	0	113
8	1	0	2	1	4
2IU-1EO					
8	5	4	0	0	9
7	1	4	13	0	18
1IU-2EO					
9	0	0	1	1	2
8	1	0	0	2	3
7	1	0	83	3	87
Total	57	23	198	22	300

Table 15: Patterning of low vowels in languages with ATR harmony

If there is a contrast among ATR high vowels in a language's inventory (2IU systems), the low vowel is licensed to alternate in harmony. It may have a [+ATR] phonemic counterpart with which it alternates, as in 8 and 10 vowel systems, or it may have a [+ATR] allophonic counterpart as in 7 or 9 vowel systems, as previously noted by Casali (2003, 2016). This allophonic counterpart can be [e] or [o], or a central vowel such as [ə]. Nevertheless, licensing does not mean that the low vowel is *required* to alternate, even in 10 vowel systems.
On the flip side, if there is no contrast among high vowels and only contrast among mid vowels (1IU systems), then it is highly unlikely for /a/ to alternate for ATR. There are no attestations of [+ATR] allophones, and though such languages may have mid +ATR central vowels, in only one language, Wolof, does the /a/ alternate with a [+ATR] counterpart.

Acknowledgements

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