Schwas in Moro Vowel Harmony

Amanda Ritchart and Sharon Rose

1. Introduction

Moro is a Kordofanian language spoken in the Nuba Mountains of Sudan. It has a vowel height harmony system that presents an intriguing challenge due to the dual nature of the central schwa vowel. Schwas in some morphemes can trigger vowel harmony, while schwas in other morphemes do not. In addition, schwas can appear with both sets of harmonic vowels within morphemes, raising the issue of whether these vowels are transparent to harmony or whether they participate in and are affected by vowel harmony. In this paper, we present an acoustic analysis of schwas in different verb roots, and propose that Moro has two kinds of schwas, a higher one that raises vowels, and a lower one that does not. We also propose that “transparent” vowels participate in the vowel harmony system, and are acoustically affected by harmony.

2. Description of the vowel harmony system

Moro has seven contrastive vowels /i e a o u ʌ/, according to standard descriptions (Black & Black 1971, Gibbard et al. 2009). These vowels are encoded in the orthography with separate symbols (/a/ are written ë respectively). It has a ‘one-step’ height harmony system, in which the lower vowels /e a o/ raise to their higher counterparts [i ʌ u], as shown below for verbs. Each verb form in (1) consists of a root with prefixes and a suffix (1SGM-CL-CLAUSE-ROOT-PFV). The effects of vowel harmony triggered by the root vowel are seen on the affixes. All data in this paper are from the Thetogovela dialect of Moro (orthographically Đotogovala).

(1)

a. é-ɡ-a-vâð-ò ‘I shaved’

b. é-ɡ-a-ved-ò ‘I knocked’

c. é-ɡ-a-tôd-ò ‘I woke up’

d. í-ɡ-ʌ-vaɡ-ú ‘I miscarried’

e. í-ɡ-ʌ-kiô-ú ‘I opened’

f. í-ɡ-ʌ-ɡurt-ú ‘I waited for’

Similar effects are seen with the locative prefix that appears on nouns in (2); this prefix may be either [e] or [i] in accordance with the vowels of the noun stem:

(2)

a. é-lôɡopájá ‘in the cup’

b. é-ɡ-jâñá ‘in the milk’

c. í-lûtí ‘in the owl’

d. í-ô-li ‘in the manure’

e. í-ɡ-â-kiô-ú ‘I opened’

In the Moro harmony system, the low vowel /a/ raises to mid [ʌ] and the mid vowels /e o/ raise to high [i u], so relying on the binary feature [+/-high] to capture the harmony system requires some abstraction from the surface pronunciation, such as treating the low and mid vowels /e/ and /o/ as [-high] and the mid vowel /ʌ/ as [+high]. A scalar feature such as [open] might be more appropriate (Clements 1991, Parkinson 1996). We do not address this issue in this paper, but we refer to the lower set of vowels as ‘low’ and the higher as ‘high’.

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1 Abbreviations: SG = singular, M = masculine, CL = class (noun class concord), CLAUSE = clause type marker, PFV = perfective

There are also verb roots whose only vowel is schwa. Some of these roots do not trigger raising (3a-c) and some do (3d-f):

(3)  
a. é-g-a-市政府-ó ‘I grew’  
b. é-g-a-市政府-ó ‘I cared for a baby’  
c. é-g-a-市政府-ó ‘I broke off’  
d. i-g-市政府 "市政府-ú ‘I sipped’  
e. i-g-市政府-ú ‘I stood, covered’  
f. i-g-市政府-ú ‘I worked’

There are few minimal pairs - the verbs in (3b) and (3e) are the clearest indication of a distinction. Most nouns have more than one vowel, but there are a few (nine from our database of about 775) that contain only schwa, although none form minimal pairs. They do belong to different harmonic sets, as can be seen from the locative form:

(4)  
a. े-市政府 ‘in the squirrel’  
b. े-市政府 ‘in the herds of cattle’  
c. े-市政府 ‘in the (type of) gum tree’  
d. i-市政府 ‘in the sign’

In addition to root or stem-controlled harmony, Moro has a dominant-recessive harmony pattern in which certain extension suffixes trigger raising of preceding prefixes and root vowels, and a following suffix. These harmony-triggering suffixes are the causative -i, applicative -市政府 and passive -市政府. It is due to the behavior of these suffixes that we term Moro harmony a ‘raising’ harmony rather than a ‘lowering’ harmony. While two of these suffixes contain schwa, not all extension suffixes with schwa trigger raising. The antipassive -市政府 does not. If the anti-passive occurs with a root with a high vowel, it does not trigger lowering, and appears to be transparent to vowel harmony. In (5), two verb roots with raising suffixes are illustrated, conjugated in the 1sg perfective:

(5)  
causative –i  
é-g-a-市政府-ó  
i-g-市政府-í

passive/reflexive -市政府  
i-g-市政府-市政府-ú  
i-g-市政府-市政府-ú

applicative -市政府  
i-g-市政府-市政府-ú  
i-g-市政府-市政府-ú

antipassive -市政府  
é-g-a-市政府-市政府-ó  
é-g-a-市政府-市政府-ó

‘take care of’
é-g-a-市政府-ó
e-g-a-市政府-ó
‘pinch’

In sum, there are two kinds of schwa in both roots and suffixes: some schwas trigger raising harmony and some do not. There are several different analyses possible for the behavior of these two kinds of schwa. First, there is a ‘diacritic’ analysis, which would hold that certain schwas, or the morphemes that contain them, are marked diacritically for raising, possibly with a floating feature or a rule. Crucially, the schwa itself is not associated with the raising feature in the output. Second, there is the ‘phonological distinction’ analysis, which would hold that the two schwas are distinguished phonologically, even though they are phonetically similar or neutralized on the surface. Such an approach would be along the lines of the analysis of strong and weak i in Inuit dialects in Compton & Dresher (2011) or the analysis of Kàlñ high vowels in Hyman (2003). Third, there is the ‘fully distinct’ analysis, which maintains that there are two phonologically and acoustically distinct schwas, but they are similar enough that prior transcriptions have not differentiated them.

The behavior of the trigger and non-trigger schwas also raise questions about the characteristics of schwas that co-occur with other vowels. For example, the schwa in the root市政府 ‘pinch’ in (5) does not trigger raising. But when it occurs with a raising suffix such as -市政府 or -市政府, is it affected by the raising like the prefixes to its left? Or is it transparent or inert to raising? The same question holds for schwas that co-occur with other vowels in verb roots or nouns, such as the following forms:

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2 The causative suffix triggers merger or deletion of the imperfective suffix, resulting in -i. See Strabone & Rose (2012) for more details.
Transparency has been a thorny issue in phonological studies of vowel harmony (van der Hulst & Smith 1986, Bakovic & Wilson 2000, Gafos & Dye 2011). In some analyses, a transparent vowel undergoes harmony, but then problematic feature combinations are “repaired” or alternately interpreted at the surface level (e.g. Clements 1977, Finley 2009, Jurgec 2011). Under other analyses, they are skipped (Pulleyblank 1996, Nevins 2010), with different methods of addressing the issue of ‘strict’ segmental locality. Finally, some studies have shown that they participate to some degree in vowel harmony. For example, Benuš (2005) and Benuš & Gafos (2007) show that transparent front vowels in back contexts in Hungarian are pronounced further back. More strikingly, Gick et al. (2006) and Kenstowicz (2009) show, based on data from two different speakers, that Kinande ‘transparent [a]’ constitutes two separate low vowels, one [+ATR] and one [-ATR]. In light of these studies, it is useful to examine the Moro data more closely with an acoustic study. This may determine whether transparent schwas are skipped or are participants, and it may help sort out if the two kinds of schwa in verb roots are acoustically distinct. We therefore designed materials to assess i) whether there is an acoustic distinction between non-trigger schwas and trigger schwas in verb roots (a test for distinct vowels), ii) whether schwas in verb roots are raised when an extension suffix is added (a test for participation) and iii) whether schwas in longer roots are distinguished due to the other vowel in the root (a test for participation).

3. Methods
3.1. Subject

One adult male speaker of the Thetogovela dialect, Elyasir Julima, participated in the study. He also speaks Sudanese Arabic and English.

3.2. Materials

Materials were constructed to elicit the non-schwa vowel inventory of the language (henceforth the “peripheral” vowels for convenience, although we recognize that [a] is not peripheral in the vowel space), so verb forms with affixes that contained each of the three /e a o/ vowels were chosen, as well as verb forms in which the tone pattern was constant. In addition, specific constructions were selected that contained instances of schwas in “low” harmony contexts, “high” harmony contexts, and “raised” contexts, where the causative –i suffix triggers raising across the word. The causative suffix was chosen, as it is the most straightforward to add to a variety of verb roots from a semantic perspective.

Materials containing vowels other than schwa consisted of CVC verb roots with the vowels /i e a o/ conjugated in the 1st singular perfective, for a total of 15 verbs. Some examples are given in (7):

(7) a. ę-g-a-vəd-a-o  ‘I shaved’
   b. i-g-a-vəd-a-u  ‘I miscarried’

There is a paucity of CVC verb roots in Thetogovela Moro that contain /u/, so this vowel was only represented in the suffix.

A total of 15 causative forms (containing the suffix –i) of the lexical vowel CVC forms were also constructed, since the causative suffix triggers vowel raising across the verb form. For example:

(8) a. i-g-a-vəd-a-i  ‘I made to shave’
   b. i-g-a-vəd-a-i  ‘I made to miscarry’
As can be seen in (8a), the /a/ is raised to [ʌ] due to the causative suffix.

For the materials containing schwa, both CVC (short root) and CaCVC (long root) contexts were used. A total of 12 verbs with a short root and 4 verbs with a long root were used. There were 6 short roots with schwa that trigger harmony and co-occur with high affix vowels (henceforth ‘trigger schwas’) and 6 short roots with schwas that do not trigger harmony and co-occur with low affix vowels (henceforth ‘non-trigger schwas’). For the long root contexts, there were 2 verbs with the pattern CaCaC (low schwas) and two with the pattern CaCaC (high schwas) that trigger raising. The small number of these latter verbs is due to their rarity in the lexicon. Examples of both are shown in (9):

(9) a. é-g-a-pag-ô ‘I weeded’  c. i-g-ʌ-pað-ú ‘I fought’ (short root)
   b. é-g-a-vadað-ô ‘I swept’ d. i-g-ʌ-maloð-ú ‘I exchanged’ (long root)

It was not possible to control for co-articulatory effects of surrounding consonants, other than not to take measurements at the vowel edges. However, we note that in many cases, the consonants are similar (see the appendix), and in the case of causatives, they are identical since the same verb roots are used.

For the trigger and non-trigger schwas in CVC roots, materials with the causative –i suffix were also created, for a total of 12 verbs (6 of each). In these forms, the causative suffix triggers raising across the verb form. For example:

(10) i-g-ʌ-pag-i ‘I made to weed’ (raised non-trigger schwa)
    i-g-ʌ-pað-i ‘I made to fight’ (raised trigger schwa)

Thus, a total of 30 CVC verb root forms with peripheral vowels and 28 verb forms containing schwa were used. Acoustic data on peripheral vowels was compiled both from vowels in the root and from affixes. Acoustic data on schwa were compiled from vowels in the root. See the appendix for a complete list of materials.

3.3. Procedures

All data were recorded by the second author in the speaker’s home on a PMD 660 Marantz recorder with an external microphone sampled at 44.1 kHz. The speaker was asked to say each verb form aloud from a list of the constructed materials. Each verb form was produced four times in the same carrier sentence: kat:a ____ éréká ‘s/he said ____ yesterday’ or for the causative, kat:a ____ kakaŋ éréká ‘s/he said ‘____ Kaka’ yesterday’. Materials were written in IPA, as the speaker is more familiar with this and less so with written Moro orthography, although there are only a few symbols that differ between the two transcription systems. Glosses were provided in English, and the second author prompted the speaker by saying the Moro word if he was unsure. If there were any errors or disfluencies in the production, the speaker was asked to repeat the item.

3.4. Data analysis

Acoustic analyses were made using Praat 5.1 analysis software (http://www.praat.org). Vowel midpoints (or steady-states, if the midpoint was not steady) were marked and formant values were automatically collected using Praat scripts. For cases in which the formant tracker did not successfully identify formants, these were measured by hand.

The values of the first and second formants were extracted and uploaded to Microsoft Excel. These were used to create vowel space plots. As F1 is the acoustic correlate of vowel height, this formant was used to assess differences in schwa vowel height. Welch t-tests within Excel were used for statistical analyses to see if significant differences existed for F1 values between trigger schwas and non-trigger schwas and between schwas in low and high contexts. Formant values of the peripheral vowels and schwas were plotted using the online Vowel Normalization and Plotting Suite designed by Erik R. Thomas and Tyler Kendall (http://ncslaap.lib.ncsu.edu/tools/norm/norm1.php). In addition, duration measurements of root vowels were also taken to assess additional differences between schwas
and peripheral vowels. Duration measurements followed standard procedures for determining vowel edges. P-values < 0.05 are considered significant. Two roots with schwa, mat ‘grow’ and mat ‘sip’ were removed from analysis, since the schwa in many tokens was too short to be reliably measured, and the slight labialization in the latter may have affected formant values.

4. Results

Mean F1 and F2 and standard deviations for the peripheral vowels are provided in Table 1. The low vowels [a e o] are separated from their high counterparts [ʌ i u] F1 by an average of at least 80Hz.

<table>
<thead>
<tr>
<th>Vowel</th>
<th>Mean F1</th>
<th>Standard Deviation</th>
<th>Mean F2</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>293.23</td>
<td>25.96</td>
<td>2263.32</td>
<td>125.49</td>
</tr>
<tr>
<td>e</td>
<td>379.67</td>
<td>55.58</td>
<td>2030.30</td>
<td>85.58</td>
</tr>
<tr>
<td>u</td>
<td>343.13</td>
<td>38.45</td>
<td>1042.03</td>
<td>166.41</td>
</tr>
<tr>
<td>o</td>
<td>426.08</td>
<td>65.16</td>
<td>1068.93</td>
<td>133.06</td>
</tr>
<tr>
<td>ʌ</td>
<td>414.62</td>
<td>50.55</td>
<td>1737.46</td>
<td>171.09</td>
</tr>
<tr>
<td>a</td>
<td>556.87</td>
<td>74.29</td>
<td>1477.02</td>
<td>127.66</td>
</tr>
</tbody>
</table>

The peripheral vowels are dispersed within the acoustic vowel space as follows in Figure 1.

![Figure 1: Acoustic space of peripheral vowels.](image)

With respect to the non-trigger schwa and the trigger schwa in CVC roots, 20 tokens of each were measured. Results are given in Table 2:

<table>
<thead>
<tr>
<th>Vowel</th>
<th>Mean F1</th>
<th>Standard Deviation</th>
<th>Mean F2</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>trigger ə</td>
<td>365.21</td>
<td>49.03</td>
<td>1253.44</td>
<td>253.10</td>
</tr>
<tr>
<td>non-trigger ə</td>
<td>445.77</td>
<td>44.09</td>
<td>1154.88</td>
<td>179.26</td>
</tr>
</tbody>
</table>

The mean F1 of trigger ə is significantly different than that of non-trigger ə (p < 0.01). The non-trigger ə is followed by [o], which has a mean F1 of 422.05, whereas the trigger ə is followed by [u], which
has a mean F1 of 342.34. The difference in schwas is therefore similar to that between the back mid vowel and the back high vowel. The schwas have higher mean F2 than the mean F2 of the back vowels that follow them, so they are, on average, more central. The vowel space of the 20 schwa tokens is depicted in Figure 2.

Figure 2. Vowel space of schwas in CVC verb roots.

Non-trigger schwas in raised (causative) contexts have a significantly lower mean F1 than their non-raised counterparts (p < 0.01). The same holds true for the trigger o, which, although it has a relatively low F1 in the ‘non-raised’ environment to begin with, its mean F1 is lower in the raised environment (p < 0.01).

Table 3. Mean F1 of raised schwas in CVC roots

<table>
<thead>
<tr>
<th>Vowel</th>
<th>Mean F1 non-raised</th>
<th>Standard Deviation</th>
<th>Mean F1 raised</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>trigger o</td>
<td>365.21</td>
<td>49.03</td>
<td>302.10</td>
<td>48.70</td>
</tr>
<tr>
<td>non-trigger o</td>
<td>445.77</td>
<td>44.09</td>
<td>296.14</td>
<td>49.04</td>
</tr>
</tbody>
</table>

The vowel space of the raised and non-raised schwas are depicted in Figures 3 and 4.
As for schwas that appear with other vowels in longer CcCVC roots, there is a significant difference (p < 0.01) between the mean F1 of those that occur in a high context versus those that occur in a low context:
Table 4. Mean F1 and F2 of schwas in CaCVC roots

<table>
<thead>
<tr>
<th>Vowel</th>
<th>Mean F1</th>
<th>Standard Deviation</th>
<th>Mean F2</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>323.67</td>
<td>39.81</td>
<td>1478.59</td>
<td>152.89</td>
</tr>
<tr>
<td>low</td>
<td>456.97</td>
<td>78.34</td>
<td>1687.86</td>
<td>112.00</td>
</tr>
</tbody>
</table>

Furthermore, the F1 of the schwa in the high context (323.67) is significantly higher (p < 0.05) than the F1 of the /ʌ/ which triggers raising harmony (374.14), but is itself a mid vowel (cf. the mean F1 for ʌ in the larger sample above is 414.62). The distribution of tokens is shown in Figure 5:

Figure 5. Schwa in low CaCaC and high CaCaC roots.

It is observed in the figures presented so far that the F2 of the schwas varies, possibly conditioned by the quality of the following vowel due to co-articulation. For example, when the mean F2s of non-raised schwas (followed by back vowels) and raised schwas (followed by a high front vowel) are compared, the raised schwas show significantly higher F2 (p < 0.01), despite the large standard deviations. A summary of mean F1 and F2 values in different contexts is presented here:

Table 5. Mean F1 and F2 of schwas followed by different vowels

<table>
<thead>
<tr>
<th>Type of ʌ</th>
<th>Context</th>
<th>Mean F1</th>
<th>Standard Deviation</th>
<th>Mean F2</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>trigger</td>
<td>..ʌ-CaC-ı</td>
<td>302.10</td>
<td>48.70</td>
<td>1623.61</td>
<td>346.13</td>
</tr>
<tr>
<td>non-trigger</td>
<td>..ʌ-CaC-ı</td>
<td>296.14</td>
<td>49.04</td>
<td>1863.00</td>
<td>271.77</td>
</tr>
<tr>
<td>trigger</td>
<td>..ʌ-CaC-u</td>
<td>365.21</td>
<td>49.03</td>
<td>1253.44</td>
<td>253.10</td>
</tr>
<tr>
<td>non-trigger</td>
<td>..a-CaC-o</td>
<td>445.77</td>
<td>44.09</td>
<td>1154.88</td>
<td>179.26</td>
</tr>
<tr>
<td>high</td>
<td>..ʌ-CaCaC-u</td>
<td>323.67</td>
<td>39.81</td>
<td>1478.59</td>
<td>152.89</td>
</tr>
<tr>
<td>low</td>
<td>..a-CaCaC-o</td>
<td>456.97</td>
<td>78.34</td>
<td>1687.86</td>
<td>112.00</td>
</tr>
</tbody>
</table>

These data can be visualized by superimposing schwa tokens on the tokens of peripheral vowels (shown in grey) in Figure 6. See the discussion section for consideration of a coarticulation explanation for the behavior of schwa.
Despite some overlap in the vowel space, schwas are distinguished from peripheral vowels by duration. Duration measurements of trigger and non-trigger schwas and lexical vowels /o/ and /ʌ/ were compared in CVC root contexts. Schwas were significantly shorter (p < 0.01) than their peripheral counterparts.

**Table 6. Mean duration of schwa and peripheral vowels**

<table>
<thead>
<tr>
<th>Vowel</th>
<th>Mean duration (ms)</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ʌ</td>
<td>122.2</td>
<td>15.8</td>
</tr>
<tr>
<td>o</td>
<td>143.1</td>
<td>30.5</td>
</tr>
<tr>
<td>trigger ʌ</td>
<td>59.5</td>
<td>13.6</td>
</tr>
<tr>
<td>non-trigger ʌ</td>
<td>51.7</td>
<td>12.9</td>
</tr>
</tbody>
</table>

5. Discussion

The acoustic study revealed that the mean F1 of trigger schwas is significantly different than the mean F1 of non-trigger schwas. The mean F1 of schwas in raised contexts is also significantly different than the mean F1 of vowels in the same roots in non-raised contexts. This suggests that there are two different schwas acoustically as well as phonologically, and that schwas are indeed affected by vowel harmony, and are not transparent in the sense of non-participation. Furthermore, schwas in long roots with low vowels also showed F1 distinctions from schwas in long roots with high vowels, further confirming non-inertness to raising.

Nevertheless, it was also noted that schwas varied in F2 depending on the F2 of the following vowel. This raises the question of whether the F1 differences observed might not also be due primarily to co-articulation with the F1 of a following vowel. After all, schwas are short central vowels, prone to co-articulation. If so, then the evidence for two phonetically distinct schwas is less strong. Two possibilities present themselves. There are two phonologically distinct schwas whose phonetic variation is determined entirely by co-articulation. Or, there are two phonologically and phonetically distinct schwas whose phonetic variation is determined both by harmony and co-articulation.
It is not easy to definitively argue in favor of one of these possibilities. We note, however, that the F1 of schwas varies in ways that are not always explainable purely by co-articulation. First, when schwa is 'raised' in vowel harmony contexts, the effect is large no matter the acoustic quality of the trigger vowel. For example, while the mean F1 of trigger schwa is in between [u] and [o] in terms of F1 at 365.21 Hz, the mean F1 of the raised non-trigger schwa is much lower, not just in causative contexts (296.14 Hz), but also in long root contexts (323.67 Hz), despite the latter [a] being followed by an acoustic mid vowel [a], which has a mean F1 of 374.14 Hz. This is suggestive of a vowel harmony raising effect rather than pure co-articulation, since the vowel has higher F1 than both its non-raised counterpart and the contextual neighboring vowels. Second, the mean F1 of a non-trigger schwa is not comparable to the mean F1 of a following –o; it is lower than the mean F1 of mid vowels, placing it between [ʌ] and [a] in the vowel space. Of course, in this context, [a] is also preceded by a prefix a- that might explain the effect, but the same pattern is found for the schwa in long root contexts, despite the latter being surrounded by low [a] vowels. Thus, the low or non-trigger schwa occupies a position in between [ʌ] and [a] in terms of mean F1 and the trigger schwa occupies a position in between [u] and [o]. Notwithstanding, co-articulation does have some role to play. There is clearly fronting and raising of a that is caused by co-articulation with a following –i, as witnessed in the F1 values of the trigger schwa when subject to raising.

One means of disentangling the issue of co-articulation would be to measure the F1 of schwas in words that have only schwa. This is not possible for verbs, which always have a suffix with a peripheral vowel. Imperative forms have no prefix, so for roots with two schwas, the prediction would be that schwas further away from a suffix vowel would show less co-articulation. Some nouns and adverbs contain only schwa. However, there are only nine such nouns from our database of 775 nouns, and most are of the non-trigger variety, making comparison difficult. There are seven adverbs with only schwa: ganaŋ ‘any’, fárfar ‘neither’, xínaq ‘firm’, ndám ‘together, two’, ṣannaŋ ‘one of’, dátal ‘more’, tāŋ ‘again’. It is not possible to tell via vowel harmony whether the schwas in the adverbs are high or low, as they do not take affixation, and we have not conducted acoustic measurements.

If there are indeed two distinct schwas, it is important to reflect on how they may have emerged. Moro has synchronic vowel reduction patterns in which the peripheral vowels /i e o u/ reduce to schwa. The conditions for this pattern are not well understood, but reduction/centralization typically occurs between consonants with the addition of a prefix. In (11a), the ‘progressive’ prefix v-, which attaches to non-round vowel-initial roots, causes reduction of [i] and [e]. Some plural noun class prefixes also trigger reduction of /i e o u/ as in (11b-c) (Gibbard et al. 2009). Vowel reduction can also occur between words, as in (11d).

(11) a. k-ili-d-ʌ / k-ʌ-v-ili-d-ʌ ‘s/he is buying’
   b. ebamba ‘drum’ n-obamba ‘drums’
   c. umon ‘type of tree’ n-om’oni ‘type of trees’
   d. karṣoná njáwá → [karṣoná njáwá] ‘s/he swallowed water’

If reduction is the source of many schwas, its variable nature appears to have created numerous minimal or near-minimal pairs with other vowels, such as the following nouns, leading to a contrastive status for schwa. Acoustic measurements of these schwas are predicted to be higher or lower depending on the harmony context, but they were not the focus of this study.

(12) a. ʌ vs. a njoma ‘power’ njoma ‘gum’
   b. ʌ vs. o dólá ‘grave/horn’ dól ‘rat’
   c. ʌ vs. e ṣar ‘trash’ ṣer ‘girl’
   d. ʌ vs. i njóndni ‘honor, respect’ njóndi ‘rabbit’
   e. ʌ vs. u dəgi ‘cut, wound’ ḷugi ‘wood plank’
   f. ʌ vs. ʌ lámí ‘hedgehog’ lám ‘beard, chin’

With respect to verbs, we note that there are few CuC verb roots in Thetogovela Moro, unless they bear a causative suffix, such as ḷuq-i ‘breastfeed!’, or may have rounded due to [w]: ḷu宕-ú ‘stir!’. There are, however, CuCC roots, such as tund-ú ‘cough!’ or turt-ú ‘wait for!’. This suggests that vowel reduction has occurred in CuC roots. The related Werria dialect sometimes has [u] where Thetogovela has [a] (tone patterns in Werria are not known):
Finally, the extension suffixes that trigger raising have cognates with [i] in the related languages Tira and Otoro according to Stevenson (1943). The cognate suffix that does not trigger raising has a lower vowel:

<table>
<thead>
<tr>
<th>(14)</th>
<th>Tira</th>
<th>Otoro</th>
<th>Moro</th>
</tr>
</thead>
<tbody>
<tr>
<td>-ino</td>
<td>-inu</td>
<td>-on</td>
<td>passive</td>
</tr>
<tr>
<td>-iŋo</td>
<td>-iŋo</td>
<td>-ʊʔ</td>
<td>applicative</td>
</tr>
<tr>
<td>-dɔ</td>
<td>-dɔi/ɛdɔi</td>
<td>-dɔ</td>
<td>derivative (T/O) antipassive (M) (non-raising)</td>
</tr>
</tbody>
</table>

These comparative data and the data from contextual vowel reduction point to vowel centralization as one of the main sources of schwas in Moro. This is more likely than Moro having a large inventory of central vowels that became peripheralized in the related languages. Our hypothesis is that high vowels reduced to a higher schwa, whereas mid vowels reduced to a lower schwa; vowel reduction maintained height distinctions in accordance with vowel harmony. Based on the internal and comparative evidence and the acoustic data, we therefore prefer the ‘fully distinct’ analysis of two schwas, both phonologically and phonetically. However, we acknowledge that the alternate analysis of neutralization to a single schwa, which is co-articulated with its neighbors, is not definitively ruled out.

Finally, it would be fruitful in future research to examine whether there is a perceptual difference between the two central schwa vowels. It is possible that they are indeed articulated differently with acoustic consequences, but that the perceptual system neutralizes these differences, perhaps in part due to the low functional load. In Moro, there are few words that contain only schwa, and few minimal pairs. Cases of such perception/production mismatches, or near mergers, are attested in the literature and include the recently analyzed cases of Cantonese mid tone (Yu 2007) or Blackfoot final voiceless vowels (Gick, Bliss, Michelson & Radanov 2012).

6. Conclusion

In this paper, we have presented data from Moro vowel harmony that examines the issue of whether Moro has two distinct schwa vowels. Height harmony raises low vowels to mid and mid vowels to high. Schwas appear to participate, raising from a low-mid position to a high-mid position in the vowel space. Furthermore, some schwas also participate as triggers. We proposed that distinct schwas may have emerged from centralization and reduction of peripheral vowels, which continue to participate in the harmony system, both as triggers and as targets. Nevertheless, some degree of co-articulation is also at work, obscuring the argument in favor of two distinct phonological and acoustic vowels. Future research will expand the number of speakers and address the co-articulation issue more thoroughly.

Appendix
References


