VOWEL CONTRASTS IN SAYSIYAT (SAISIYAT)

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1 Introduction

In this paper, we investigate a set of vowel contrasts in the vowel system of SaySiyat (Saisiyat), a Formosan language, that is, an Austronesian language of Taiwan.[1] SaySiyat is spoken by a community of around 7,000 people in Hsinchu and Miaoli counties in northwest Taiwan (Ethnologue; Zeitoun, Chu and kaybaybaw 2015, henceforth "ZCK"). SaySiyat is an endangered language, with speaker estimates running from a few hundred (ZCK) to a few thousand (Ethnologue). All SaySiyat speakers are multilingual, speaking the languages of the surrounding Atayal and Hakka Chinese communities, as well as the national languages Taiwanese (Minnan) and Mandarin. This study uses data collected by the first author from a single speaker of SaySiyat.

According to previous studies (e.g., Li 1978, Yeh 1991, 2000, Zeitoun & Wu 2005, Hsieh 2008, ZCK), SaySiyat has a vowel inventory /i æ a o œ ə/, which differs from the vowel space proposed for Proto-Austronesian *i *a *u *ə and found in several other Formosan languages (Blust 2013), with the addition of two vowels /æ œ/ characterized as front vowel reflexes of the central and back vowels /a o/. These front vowels /æ œ/, which occur in the context of [ʔ h], contrast with the central back vowels /a o/ in some lexical items, but are otherwise in complementary distribution with them (Li 1978, ZCK). In this paper, we provide an acoustic study of the SaySiyat vowel inventory, and in particular of the front-central pair /æ ~ a/ and the front-back /œ ~ o/.

Our preliminary finding is that /a/ is fronted in the context of [h] and that the front vs. central distinction between /æ ~ a/ is neutralized in this context. On the other hand, /a/ is not fronted in the context of [ʔ] and is distinct from /æ/ in this context. /o/ is not fronted in the context of either of [ʔ h], and is distinct from /œ/ in the context of [h] and likely of [ʔ], as well. These findings suggest that SaySiyat retains the vowels /æ œ/ but that /æ/ is partly neutralized with /a/.

[1] "SaySiyat" is the name of the language in the community orthography. The terms "Saisiyat" or "Saisiat" are used in the linguistic literature on SaySiyat (e.g., Tsuchida 1964, Li 1978, Yeh 1991, Zeitoun & Wu 2005). In this paper, we use the spelling "SaySiyat" throughout.

2 Vowel Systems in Formosan Languages

Formosan languages form several different branches of the Austronesian language family; all other Austronesian languages form a single branch, Malayo-Polynesian (Blust 1977, 1999, 2013, Ho 1998, Sagart 2004, Ross 1992). Proto-Austronesian is hypothesized to have the vowel system /i a u ə/ (Ross 1992, Blust 2013). According to Blust, this vowel system is common in Formosan languages: Formosan languages "usually have … four vowels (the vowel 'triangle' plus schwa)" (2013:54) and "a number of Formosan vowel systems … retain the PAN [= Proto-Austronesian] four-vowel system *i, *u, *a, *e (schwa)" (2013:173). According to Becker-Kristal's (2010) vowel inventory classification system, the inventory /i a u ə/ is 3S1: three peripheral vowels in a symmetrical arrangement /i a u/ with a one non-peripheral vowel, a centroid /ə/.

Becker-Kristal's classification of the Formosan languages Paiwan and Rukai as 3S1 (2010:190) follows Chen's (2006) description of the vowels. According to Chen, Paiwan has the vowel system /i a u ə/. Chen also mentions the vowel /o/, which he calls "a loan vowel ... associated with Japanese, Taiwanese, or Mandarin loanwords" (2006:69-70), and he does not include /o/ in the native vowel system. Chen classifies /ə/ as a full vowel in Paiwan, with distribution restrictions. He notes that it "never appears word-initially ... or in diphthongs" (2006:70). The Budai dialect of Rukai has the same vowel inventory /i a u ə/, but with corresponding long vowels /i: a: u: ə:/ (Chen 2006:231-2).

Chen reports that both Paiwan and Budai Rukai have conditioned alternations of these vowels in the context of back consonants. For Paiwan, lowered allophones [e o] of /i u/ appear adjacent to the uvular stop [q] and a backed allophone [ɑ] of /a/ adjacent to velar and uvular consonants. Chen states that the allophones [e ɑ o] are in free variation with their corresponding vowels [i a u] (2006:73-74). In Budai Rukai, /i a/ have the allophones [e ɑ] adjacent to velar consonants, in free variation with [i a] (Chen 2006:237-9). On the other hand, Chen also states that [o] is in free variation with [u] "in many unpredictable contexts" (2006:238).

A few other Formosan languages have vowel systems different from this inventory. Squliq Atayal has a five-vowel system /i e a o u/ (Der-Hwa 1992), which is 5S0 in Becker-Kristal's (2010) classification (five peripheral vowels, symmetrically arranged, no non-peripheral vowels). Tsou has a six-vowel system /i e a o u ɨ/ (Wright & Ladefoged 1994), classified as 5S1, adding one non-peripheral vowel to the 5S0 system. According to Li (1977) and Hsin (2000), Maga Rukai has a seven-vowel system /i e a o u ɨ ə/, though Hsin argues that "the distinction between high and mid vowels is only a surface phenomenon" (2000:34, 75). The Formosan languages reviewed all have triangular systems; the peripheral vowels are either /i a u/ (Paiwan, Budai Rukai) or /i e a o u/ (Squliq Atayal, Tsou, Maga Rukai), while the non-peripheral vowels are /ə/ (Paiwan, Budai Rukai), /ɨ/ (Tsou), or both (Maga Rukai).

3 SaySiyat Vowel System

Previous literature reports that SaySiyat has the following vowel inventory: /i æ a o œ ə/ (Li 1978, Yeh 1991, 2000, Zeitoun & Wu 2005, Hsieh 2008, and ZCK). The SaySiyat vowels /æ œ/ do not occur in any of the other Formosan languages reviewed above. Tsuchida (1964:49) reports a seventh vowel /e/, but states that it is likely "an allophone of /i/." All later studies agree that [e] is an allophone of the high front vowel /i/. As suggested by their IPA values, most studies of SaySiyat take /æ œ/ to be low unrounded and mid-low rounded front vowels, respectively (Tsuchida 1964,

Li 1978, Yeh 1991, 2000, Hsieh 2008; c.f. Zeitoun & Wu 2005, discussed below). If schwa in SaySiyat is a full vowel, as Chen (2006) claims for the Formosan languages Paiwan and Budai Rukai, then the SaySiyat system would be 4L2, with the non-peripheral central /ə/ and front rounded vowel /œ/ (according to Becker-Kristal, front rounded vowels serve as non-peripheral). The SaySiyat vowel system is thus different from the triangular systems of the other Formosan languages seen above. Figure 1 shows the inventory /i æ a o œ ə/ in a vowel chart.

	Front		Central	Back
	Unrounded	Rounded	(Unrounded)	(Rounded)
High	i			
Mid-High			ə	o
Mid-Low		œ		
Low	æ		a	

Figure 1. Proposed SaySiyat Vowel Chart: /i æ a o œ ə/

This paper investigates the status of the two vowels /æ œ/, which are not reported for other Formosan languages. We are interested in both the position of /æ œ/ in the SaySiyat vowel system as a whole, and the relation of /æ/ to /a/ and /œ/ to /o/, specifically. There are two major issues to consider: first, are there lexical contrasts between [æ œ] and [a o], and second, do [æ œ] and [a o] participate in alternations patterns, where [æ œ] are found next to [ʔ h] and [a o] elsewhere?

Tsuchida (1964), Li (1978) and Hsieh (2008) report that the SaySiyat vowels [æ œ] occur primarily next to the glottal sounds [ʔ h]: [æ œ] "rarely occur except contiguous to /h/ or /ʔ/" (Tsuchida 1964:49), are "generally conditioned by the glottal sounds" (Li 1978:139), and "usually appear in the environments where /ʔ/ or /h/ is adjacent" (Hsieh 2008:12). However, it has been reported that the vowels [a o] can also occur adjacent to [ʔ h]. As we see in examples in (1) and (2), lexical contrasts may occur with [æ~a œ~o]. (1-2) show the contrast between [æ œ] (2a-c) and [a o] (1a-c) adjacent to [ʔ].

(1) a. [ʔinar**o**ʔ] 'long'	(2) a. [ʔinor**œ**ʔ] 'tunnel'	(Hsieh 2008:12)
b. [tiim**a**ʔ] 'to wash hands'	b. [tatim**æ**ʔ] 'dish, vegetable'	(ZCK 2015:20)
c. [t**o**ʔt**o**ʔ] 'to hit (with fist)'	c. [t**œ**ʔ**œ**is] 'back of hand'	(ZCK 2015:20)

Thus, [a o] can occur in the context of [ʔ h], where they contrast with [æ œ]. (3-4) show that [a ~ æ] and [o ~ œ] also contrast in a syllable adjacent to an identical vowel in the context of [ʔ h]. In (3), central and back vowels [a o] occur both in the context of [ʔ] and in the preceding syllable; in (4), front vowels [æ œ] occur both in the context of [ʔ] and in the preceding syllable, as well.

(3) a. [t**a**t**a**ʔ] 'millet'	(4) a. [t**æ**t**æ**ʔ] 'to chew thoroughly'	(Li 1978:139)
b. [t**o'o**ʔ] 'three'	b. [β**œ'œ**ʔ] 'sp. of slender bamboo'	(Tsuchida 1964:49)

(3-4) may be examples of harmony between adjacent vowels. According to Li, "a few forms manifest vowel harmony, e.g., /tætæʔæŋ/ 'lizard'" (1978:139). Hsieh (2008) gives a detailed treatment of harmony between vowels in adjacent syllables in SaySiyat, focusing on affixes and epenthesis, where the affix and epenthetic vowels harmonize with the vowel of the root.

According to Li (1978:141), the contrast between [a ~ æ] and [o ~ œ] adjacent to [ʔ h] is due to two sound changes. [æ œ] are the SaySiyat reflexes of Proto-Austronesian (henceforth "PA") *a *u next to PA *q *s, which otherwise became [a o] in SaySiyat. Then *q collapsed with PA *Q

*W *H into SaySiyat /ʔ/ and *s collapsed with PA *S *θ *H *x into SaySiyat /h/, which neutralized the environment that triggered [æ œ], contrasting with [a o] adjacent to /ʔ h/.

Apart from the contrasts like those found in (1-4), which previous literature reports to be a small number (Tsuchida 1964, Li 1978, ZCK, [æ œ appear in complementary distribution with [a o]. As illustrated by (5-8), [æ œ] occur next to [ʔ h] (underlined), while [a o] occur elsewhere (bolded and italicized).

(5) [p***o***.ŋæh] 'flower' (Li 1978:139)
(6) [ʔœ.w***a***y] 'rattan' (Li 1978:139)
(7) [ti.n***a***l.ʔœ.mæh] 'year' (fieldwork)
(8) [s***a***.βœh] 'all, together' (fieldwork)

In addition, [a o] and [æ œ] alternate in morphemes like the infix /om/ ACTIVE.VOICE.REALIS and the prefix /Ca-/ INSTRUMENTAL.NOMINALIZER (where 'C' is a reduplicated consonant).[2] This alternation depends on whether [ʔ h] are adjacent to the infix vowels /a o/, in which case the allomorphs [Cæ-] INST.NMLZ and [-œm-] AV.RL occur, as shown in (9-10). In (9-10), the roots begin with [h] and [ʔ], respectively, seen from the AV.IR forms in (9a, 10a). Note that the first vowel of the root in (10) is [æ] in (10a-b), but [***a***] in (10c), when it is not adjacent to [h]; the same is true of (11), with the root vowel [œ] in (11a-b), but [***o***] in (11c), when it is not adjacent to [ʔ]. Following ZCK, we propose that the initial vowel phonemes are /a o/ in these words, which are fronted to [æ œ] in the context of [ʔ h] (see also Hsieh 2008:12).

(9)	a. [hæop]	b. [hae-haeop]	c. [h-œm-***a***op]	
	/haop/	/Ca-haop/	/<om>, haop/	
	'winnow' (AV.IR)	'winnowing basket'	'winnow' (AV.RL)	(ZCK 2015:44-45)
(10)	a. [ʔœral]	b. [ʔæ-ʔœral]	c. [ʔ-œm-***o***ral]	
	/ʔoral/	/Ca-ʔoral/	/<om>, ʔoral/	
	'rain' (AV.IR)	'rain' (noun)	'rain' (AV.RL)	(ZCK 2015:45)

Compare with (11), which shows the allomorphs [Ca-] INST.NMLZ and [-om-] AV.RL, where there is no [ʔ h] adjacent to the vowels in these morphemes.

(11)	a. [kitaʔ]	b. [k***a***-kitaʔ]	c. [k-***o***m-itaʔ]	
	/kitaʔ/	/Ca-kitaʔ/	/<om>, kitaʔ/	
	'see' (AV.IR)	'glasses'	'see' (AV.RL)	(fieldwork)

In summary, the front vowels /æ œ/ are in near-complementary distribution with the central and back vowels /a o/: /æ ~ a/ and /œ ~ o/ are lexically contrastive in the context of [ʔ h] in some words (1-4), but otherwise [æ œ] only occur in the context of [ʔ h] and [a o] elsewhere (5-11), suggesting that [æ ~ a] and [œ ~ o] are also allophones of phonemes /a o/. We will thus investigate the acoustic properties of /æ ~ a/ and /œ ~ o/ to see whether their formant values differ significantly. Zeitoun & Wu state that /æ œ/ are "very close" in backness to /a o/ and that a "merger between a/æ … and o/œ is in progress" (2005:31fn2), suggesting to us that in each pair /æ ~ a/ and /œ ~ o/,

[2] In this paper, we use the following morpheme abbreviations: AV.RL for ACTIVE.VOICE.REALIS, AV.IR for ACTIVE.VOICE.IRREALIS, and INST.NMLZ for INSTRUMENTAL.NOMINALIZER.

the two vowels are close to each other in the acoustic space. However, they do not give any data to support this assertion; we provide data to investigate how close /æ ~ a/ and /œ ~ o/ are in the vowel space.

4 Present Study

The present study investigates the vowel system of SaySiyat through an acoustic analysis of the vowels of a single speaker of SaySiyat. We look at both the vowel system and the contrasts between /æ ~ a/ and /œ ~ o/.

4.1 Speaker

Our language consultant, ʻoemaw a ʻobay tawtawazay (Chao Shan-He), is a male native speaker of the northern (Taai) dialect of SaySiyat. ʻOemaw was raised in a SaySiyat-speaking environment but has resided outside the community in Chinese-majority cities for several decades. He is active in maintaining SaySiyat language and culture and travels to his native village often. ʻOemaw is multilingual, speaking Atayal (another Formosan language), Japanese and three Chinese languages: Hakka, Minnan (Taiwanese) and Mandarin. The fact that he speaks several different languages and primarily uses either Mandarin or Minnan in everyday life, not SaySiyat, presents a confound in our data. This is an intractable problem with SaySiyat, since there are no monolingual speakers and the SaySiyat communities are heavily acculturated to the larger neighboring Atayal and Hakka communities (Zeitoun and Wu 2005, ZCK 2015). Note that ʻoemaw has served as a language consultant for many of the previous studies of SaySiyat cited in Section 2.1, including Yeh (2000), Hsieh (2008) and ZCK.

4.2 Materials

We took 414 vowel tokens from 90 distinct words appearing in five narratives on SaySiyat folk stories, custom, and other aspects of SaySiyat culture recorded by the first author in June 2013, supported by a Tsai Fund summer fellowship from the University of Southern California. All the narratives were recorded at the speaker's house in Nangang, Taipei, using a laptop computer's built-in microphone, resulting in varying quality of recording. Each narrative was translated into Mandarin by the speaker after speaking the entire narrative in SaySiyat. The narratives were transcribed by the second author, a native speaker of Mandarin, in the Phonetics Lab in the Department of Linguistics at the University of Rochester. The second author used two lexicons to aid her in transcription: Li's (1978) *Saisiyat Vocabulary* and the SaySiyat-Chinese *Aboriginal Languages Online Dictionary* (henceforth "ALOD," Aboriginal Committee, 2016). The labels for each token were taken from ALOD to prevent any bias on the part of the authors in determining the vowel category. We note, however, that this lexicon differs from some previous sources in transcribing certain words.

4.3 Methods

Formant values of all vowel tokens were recorded in Praat (version 6.0.41; Boersma & Weenink 2018) using a script from Christian DiCanio (http://www.acsu.buffalo.edu/~cdicanio/scripts.html). We took ~~the~~ formant values at the midpoint of each vowel, and calculated their means and standard deviations. We examined tokens whose formant values were more than 2 standard deviations from the mean and checked their formants by hand in Praat.

5 Results

5.1 Vowel System

Table 1 provides the means~~s~~ and standard deviation~~s~~ of the vowel system /i æ a o œ ə/. The vowel symbols for each token are based on ALOD in the SaySiyat community orthography. Note that the difference in the mean of F2 of [œ o] is 102 Hz, the SD is 186 Hz and 212 Hz, respectively, while the difference in the mean of F2 of [æ a] is 116 Hz and the SD is 116 Hz and 143 Hz, respectively.

Table 1. Vowel Formant Measurement (with Means and SDs, in Hz)

Vowel	F1	F2	F3	# of Tokens
i	395 (63)	1973 (141)	2760 (267)	57
æ	715 (91)	1609 (116)	2627 (195)	75
a	703 (96)	1493 (143)	2635 (259)	156
o	500 (75)	1254 (212)	2605 (355)	61
œ	507 (74)	1356 (186)	2556 (371)	23
ə	557 (106)	1508 (196)	2677 (332)	42

Figure 2 is a vowel plot of the F1 and F2 values of all 414 vowel tokens in our data set. Note the overlap between the tokens of the vowel pair [æ a] (purple and light green) as well as between the tokens of the vowel pair [œ o] (blue and red).

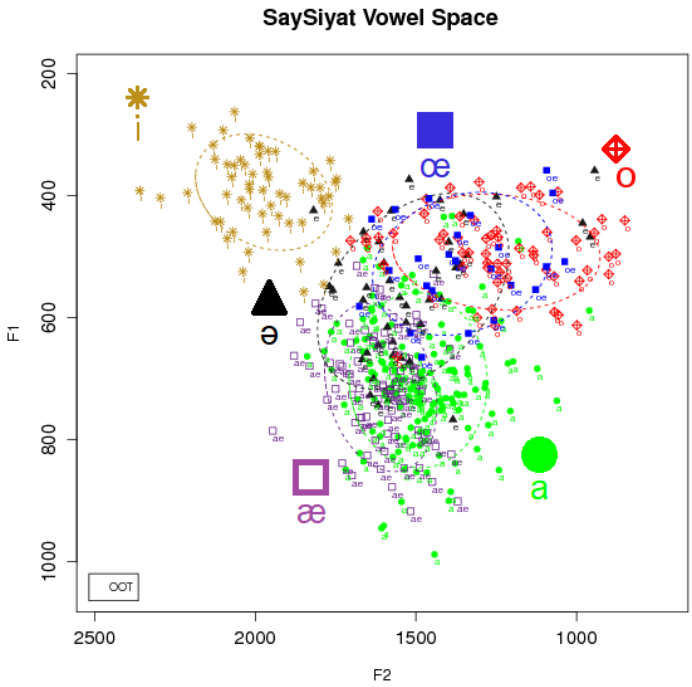

Figure 2. SaySiyat Speaker's Vowel Space[3]

Figure 3 is a plot of the mean and two standard deviations of F1 and F2 of the tokens of the SaySiyat vowels. Note that in both vowel pairs [æ a] and [œ o], the mean F2 value of each member of the pair is one SD or less away from the mean F2 value of the other member of the pair, as also seen in Table 1 above.

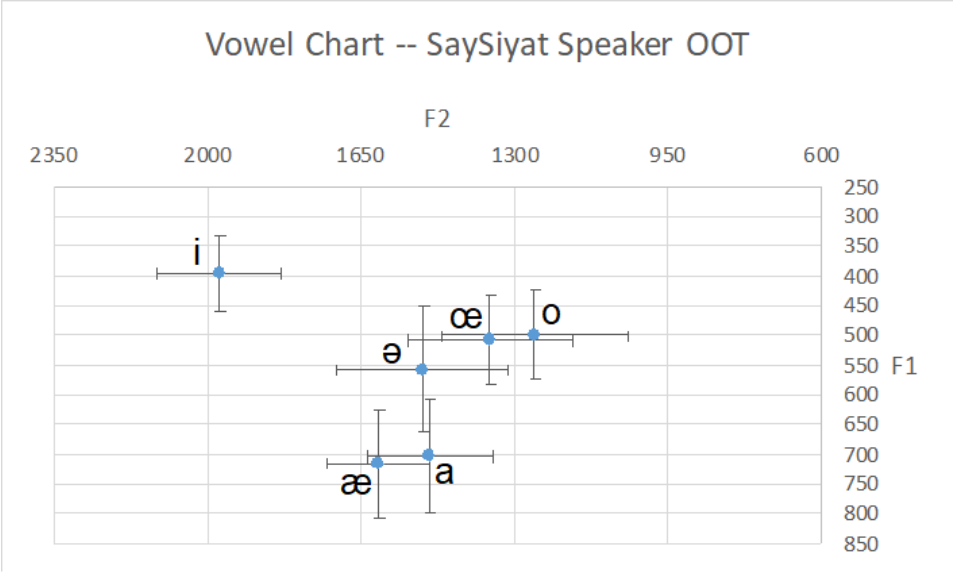

Figure 3. SaySiyat Vowel Chart: Means and SDs

[3] Figure 2 has been drawn at the NORM website (http://lingtools.uoregon.edu/norm/index.php), without normalization since we have only one speaker.

The distribution of the speaker's vowels in Table 1 and Figures 3-4 suggest that the vowel pairs /æ ~ a/ and /œ ~ o/ are close to one another in the vowel space, but still distinct. We performed T-tests on both of the pairs /æ ~ a/ and /œ ~ o/ using the measurements in Table 1, looking at differences in F2, the acoustic dimension of frontness, which distinguishes the vowels in these pairs. We found that the difference in F2 was highly significant between /æ ~ a/ (p value < .001), but was barely significant at the p = .05 level between /œ ~ o/ (p value = .046).

5.2 Vowel Contrasts: /a ~ æ/, /o ~ œ/

To examine the effects of context on the distribution, we now look at the two vowel pairs /a ~ æ/ and /o ~ œ/, and the effect of phonological environment on their F2 values. Recall that the vowels /a o/ may be conditioned by an adjacent glottal consonant [ʔ h] ((5-11); Tsuchida 1964, Li 1978, Hsieh 2008, ZCK), resulting in [æ œ]. Recall as well that lexical contrasts are found between /æ a/ and /œ o/ (1-4). Since front vowels have a higher F2 than central and back vowels, we are interested to see whether the central and back vowels /a o/ also have a higher F2 in the context of [ʔ h] than elsewhere, and whether the front vowels /æ œ/ have a higher F2 than the central and back vowels /a o/ in the same context.

We first look at the low unrounded vowels /a ~ æ/. Table 2 shows the mean F2 values and standard deviations for tokens of the vowel categories /æ a/ in the context of [h], of [ʔ], and elsewhere. We also separate the vowel tokens in the context of [j], the palatal approximant, because the vowel tokens in these contexts have a higher F2 than in other contexts. As illustrated in Table 2, the mean of F2 of /a/ and of /æ/ is highest in the context of /j/, then of /h/, then of /ʔ/, then elsewhere. For each context, the mean of F2 of /æ/ is higher than the mean of F2 of /a/. The difference in the mean of F2 of /a/ between the context of [h] and of [ʔ] is 117 Hz, between the context of [h] and elsewhere is 142 Hz, but between the context of [ʔ] and elsewhere is only 25 Hz. The difference in the mean of F2 of /æ/ in the context of [h] and of [ʔ] is also 70 Hz. The difference in the mean of F2 of /a/ and of /æ/ in the context of [h] is 51 Hz and in the context of [ʔ] is 98 Hz.

Table 2. F2 values of /æ a/ in Different Contexts

	æ		a	
Context	F2 (Mean, SD)	# of Tokens	F2 (Mean, SD)	# of Tokens
[j]	1765 (126)	11	1599 (133)	35
[h]	1643 (105)	55	1592 (128)	10
[ʔ]	1573 (100)	32	1475 (121)	38
Elsewhere			1450 (135)	77

Figure 4 is a plot of the mean and two standard deviations of F1 and F2 of the tokens of /a ~ æ/ by context from Table 2.

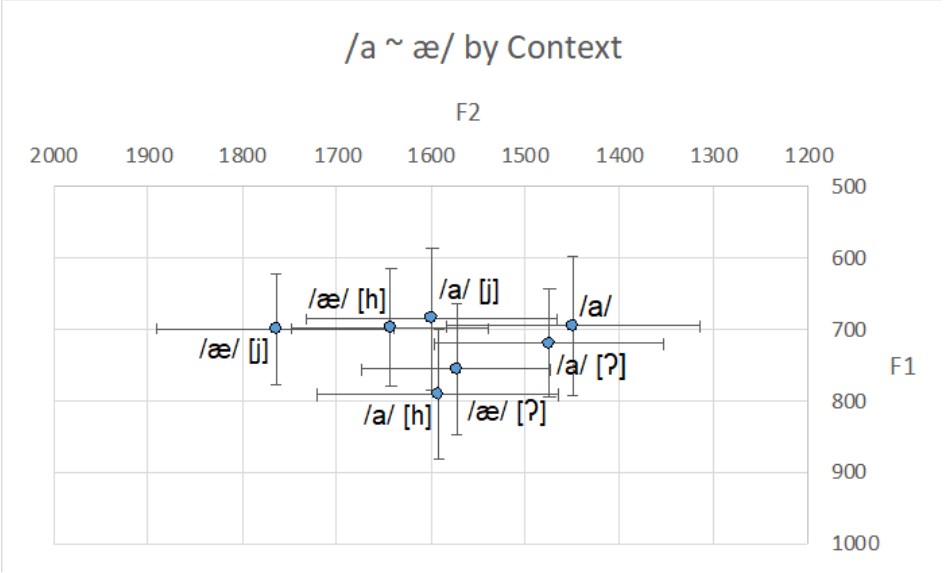

Figure 4. /æ ~ a/: Means and SDs

Using the measurements in Table 2, we performed T-tests on pairs of the groups of tokens in Table 2 (that is, the tokens of each vowel in each context) to determine whether the groups differed significantly. Table 3 shows the *p* values for the following pairs: /a ~ æ/ in the context of [h], /a ~ æ/ in the context of [ʔ], /a/ in the context of [h] and elsewhere, and /a/ in the context of [ʔ] and elsewhere.

Table 3. *p* values for groups of /a ~ æ/ in different contexts

Group 1	Group 2	*p*-value
/a/ in [h] context	/æ/ in [h] context	0.161
/a/ in [h] context	/a/ elsewhere	0.001
/a/ in [ʔ] context	/æ/ in [ʔ] context	0.0005
/a/ in [ʔ] context	/a/ elsewhere	0.336

Table 3 shows that $p < .05$ for the pairs /a ~ æ/ in the context of [ʔ] and /a/ in the context of [h] and elsewhere, that is, the two groups in each pair differed significantly for the *p* level .05. For the pairs /a ~ æ/ in the context of [h] and /a/ in the context of [ʔ] and elsewhere, $p > .05$, that is, the two groups in each pair did not differ significantly for the *p* level .05.

We now look at the mid-rounded vowels /o ~ œ/. Table 4 shows the mean F2 values and standard deviations for tokens of the vowel categories /œ o/ in the context of [j], [h], [ʔ], and elsewhere. As illustrated in Table 4, the mean of F2 of /o/ and of /œ/ are higher in the context of /h/ than of /ʔ/. For /o/, the mean of F2 is the highest in the context of /j/, and in the elsewhere context, the mean of F2 is between that found in the /h/ and /ʔ/ contexts. For /œ/, the mean of F2 is the lowest in the context of /j/, different from the pattern in other three vowels investigated; however, there is only single token of /œ/ next to [j], which may be an outlier or a transcription error. For the contexts /ʔ h/, the mean of F2 of /œ/ is higher than the mean of F2 of /o/.

The difference in the mean of F2 of /o/ between the context of [h] and of [ʔ] is 136 Hz, between the context of [ʔ] and elsewhere is 99 Hz (with the mean of F2 higher in the elsewhere context),

but only 37 Hz between the context of [h] and elsewhere. The difference in the mean of F2 of /œ/ in the context of [h] and of [ʔ] also 218 Hz. The difference in the mean of F2 of /o/ and of /œ/ in the context of [h] is 235 Hz and in the context of [ʔ] is 153 Hz.

Table 4. F2 values of /œ o/ in Different Contexts

	œ		o	
Context	F2 (Mean, SD)	# of Tokens	F2 (Mean, SD)	# of Tokens
[j]	1074	1	1360 (190)	11
[h]	1518 (88)	7	1283 (225)	7
[ʔ]	1300 (170)	15	1147 (146)	6
Elsewhere			1246 (218)	39

Figure 5 is a plot of the mean and two standard deviations of F1 and F2 of the tokens of /o ~ œ/ by context from Table 2.

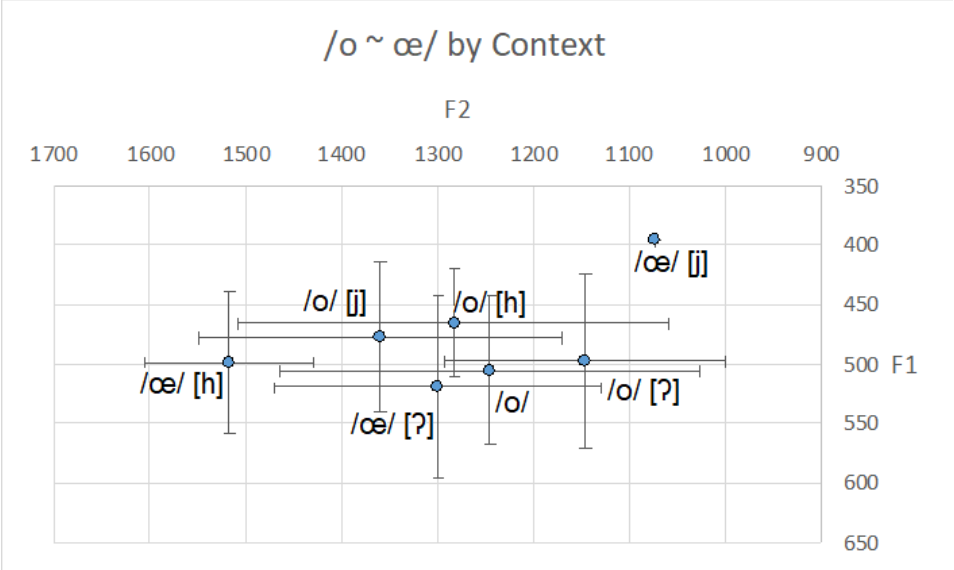

Figure 5. /œ ~ o/: Means and SDs

Using the means of F2, SDs of F2, and numbers of tokens of /œ ~ o/ in different contexts in Table 4, we performed T-tests on pairs of the groups of tokens in Table 4 (that is, the tokens of each vowel in each context) to determine whether the groups differed significantly. Table 5 shows the *p* values for the following pairs: /o ~ œ/ in the context of [h], /o ~ œ/ in the context of [ʔ], /o/ in the context of [h] and elsewhere, and /o/ in the context of [ʔ] and elsewhere.

Table 5. *p* values for groups of /o ~ œ/ in different contexts

Group 1	Group 2	*p*-value
/o/ in [h] context	/œ/ in [h] context	0.024
/o/ in [h] context	/o/ elsewhere	0.683
/o/ in [ʔ] context	/œ/ in [ʔ] context	0.069
/o/ in [ʔ] context	/o/ elsewhere	0.290

Table 5 shows that $p < .05$ for the pair /o ~ œ/ in the context of [h], that is, the two groups in each pair differed significantly for the *p* level .05. For the pairs /o ~ œ/ in the context of [ʔ], /o/ in the context of [h] and elsewhere, and /o/ in the context of [ʔ] and elsewhere, $p > .05$, that is, the two groups in each pair did not differ significantly for the *p* level .05, though the difference between the pair /o ~ œ/ in the context of [ʔ] was close to the significance level. It is important to keep in mind that the number of tokens for /œ o/ is small (15 or fewer) for every context except for /o/ in the elsewhere context.

6 Discussion

The results above shed light on the question of how close the members of each pair /æ ~ a/ and /œ ~ o/ are in the vowel space and the effect of context. We focus on F2, the acoustic measurement of tongue body fronting, as the pairs /æ ~ a/ and /œ ~ o/ are distinguished by fronting. For the low unrounded vowels /æ ~ a/, we did not find a significant difference in the F2 of /æ/ and /a/ in the context of [h], but we found a significant difference in the F2 of /a/ in the context of [h] and in the elsewhere context. With the context of [ʔ], we found the opposite results: a significant difference in the F2 of /æ/ and /a/ in the [ʔ] context, but no significant difference in the F2 of /a/ in the [ʔ] vs. the elsewhere context.

We interpret these data to mean that in our speaker's speech, /a/ in the context of [h] is fronted compared to /a/ elsewhere, and fronted /a/ is not distinct in from /æ/ in the context of [h]. On the other hand, /a/ in the context of [ʔ] is not fronted compared to /a/ elsewhere, and retains its acoustic distinction from /æ/ in the same context. In this speaker's speech, the /a ~ æ/ distinction is likely neutralized in the context of [h] but not of [ʔ].

For the mid rounded vowels /œ ~ o/, we found a significant difference in the F2 of /œ/ and /o/ in the context of [h], but no significant difference in the F2 of /o/ in the [h] context vs. the elsewhere context. In the [ʔ] context, the difference in the F2 of /œ/ and /o/ did not quite reach significance, and there was no significant difference in the F2 of /o/ in the [ʔ] context vs. the elsewhere context. We interpret these results to mean that for our speaker, /o/ in the context of [ʔ h] has not fronted compared to /o/ elsewhere, and that /œ ~ o/ are distinct in the context of [h] and likely in the context of [ʔ] as well.

We briefly consider why the vowels /æ œ/ are restricted to the context of the glottal consonants [ʔ h], and why fronted allophones [æ œ] of /a o/ appear in this context. A higher F2 resulting from tongue body fronting is not the expected result of the vowels /a o/ in coarticulation with the glottal consonants [ʔ h]. Glottal consonants do not involve tongue body articulation, and should not affect tongue position. Guekguezian and Iskarous (2017) suggest that the consonant transcribed as <h>, at least, is actually pharyngeal [ħ], and that it may have the coarticulatory result of fronting low vowels if [ħ] is produced with tongue bunching. In the context of the palatal glide [j], higher F2

resulting from tongue fronting is the expected result of coarticulation, since [j] shares articulatory position with the high front vowel /i/ (Ladefoged & Maddieson 1996).

7 Conclusion

This study has provided data on the vowel system of SaySiyat, and the vowel pairs /æ ~ a/ and /œ ~ o/, which show a limited contrast in the context of [ʔ h]. According to the data in this study, /æ ~ a/ do not contrast in the context of [h], but do contrast in the context of [ʔ], while /œ ~ o/ contrast in the context of [h] and likely in the context of [ʔ] as well. We emphasize the limitations of our study: we have only one speaker, who is multilingual and does not use SaySiyat as his primary language; the tokens are taken from narrative speech in poor acoustic conditions; there are only a small number of tokens of /œ o/.

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