Colloquial Arabic vowels in Israel: A comparative acoustic study of two dialects

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This study explores the acoustic properties of the vowel systems of two dialects of colloquial Arabic spoken in Israel. One dialect is spoken in the Galilee region in the north of Israel, and the other is spoken in the Triangle (Muthallath) region, in central Israel. These vowel systems have five short and five long vowels /i, i:, e, e:, a, a:, o, o:, u, u:/. Twenty men and twenty women from each region were included, uttering 30 vowels each. All speakers were adult Muslim native speakers of these two dialects. The studied vowels were uttered in non-pharyngeal and non-laryngeal environments in the context of CVC words, embedded in a carrier sentence. The acoustic parameters studied were the two first formants, F0, and duration. Results revealed that long vowels were approximately twice as long as short vowels and differed also in their formant values. The two dialects diverged mainly in the short vowels rather than in the long ones. An overlap was found between the two short vowel pairs /i/-/e/ and /u/-/o/. This study demonstrates the existence of dialectal differences in the colloquial Arabic vowel systems, underlining the need for further research into the numerous additional dialects found in the region.
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I. INTRODUCTION

Arabic is spoken by more than 250×10^6 native speakers over large parts of the world, mainly around the Mediterranean, in North Africa and the Middle East. Arabic speaking immigrants also reside in Europe and the other continents. This language and its phonetic system have therefore gradually begun to attract more linguistic attention.

More than many other languages, Arabic is known for its diglossia, i.e., the existence of Colloquial Arabic (CA) dialects, the "Low" varieties, in addition to the "High," written standard (Modern Standard Arabic, MSA) variety (Ferguson, 1959; Kaye, 1994). Differences between MSA and CA exist on all linguistic levels at different degrees in each dialect.[1]

This study investigates the vowel systems of two dialects of CA spoken in Israel. The acoustics of these vowel systems have been studied very little, although there are some phonological descriptions of Arabic dialects spoken in Israel. In addition to the general and comparative linguistic interest in the study of Arabic dialects, defining the phonetic system of a language is a necessary foundation for many ensuing endeavors such as language analysis and synthesis (Habash, 2010), study of language acquisition (Khattab and Al-Tamimi, 2008) and planning rehabilitation programs for speech- or hearing-impaired speakers (Kishon-Rabin and Rosenhouse, 2000).

A. Arabic dialects

The Colloquial Arabic dialects in Israel (CAI) belong to the Eastern Syro-Lebanese or Levantine (Shaami /ʃa:mi/, in CA) dialect group. Although the country is small and speakers of the different dialects are often in contact, their dialects are distinct and speakers report (as an informal observation) that they are able to identify other speakers' origin by their dialects.

CAI dialects are classified into sedentary urban and rural dialects and into Bedouin (nomadic) dialects.[2] Speakers of CAI are also divided into regional dialects in the north, center and south of Israel and faith communities of mainly Muslims, Christians, Druze, and their sub-sects (Rosenhouse, 2011). In some traditional Arabic-speaking societies men and women live in rather separate social groups (except for family relations). Thus, CA reveals various linguistic differences between male and female speech (e.g., Al-Wer, 2007; Vicente, 2013; Henkin, 2000). This state is common to most of the Arabic dialects in the Middle East and North Africa and many studies of Arabic dialects focus on linguistic gender-based differences in the phonetic and lexical domains (e.g., Al-Wer, 2007; Eid, 2002). Similar phonetic-acoustic differences exist also in CAI, although studies have dealt with this topic rather sporadically (Rosenhouse, 1998).

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The Shaami CA dialect group encompasses, in addition to Israel, some dialects in the Hashemite Kingdom of Jordan, Syria, and Lebanon. Sedentary urban and rural, as well as Bedouin dialects of this region, have been researched since the beginning of the 20th century, including their phonology (e.g., see Bergsträsser, 1915, about the whole region; Abu Haidar, 1979, for Lebanon; Cowell, 1964, for Syria; Cleveland, 1963; Al-Wer, 2007, for Jordan; Bauer, 1913; Schmidt and Kahle, 1918, for Palestine; Blanc, 1953; Rosenhouse, 1984; Levin, 1994, for Israel). Thus, the phonological system of CAI has been documented, but its acoustical-phonetic features much less so.

B. CAI phonology

Arabic is a quantity language which distinguishes vowel durations (Fischer and Jastrow, 1980), like many world languages (Disner, 1983). In the case of Arabic, the MSA system has three phonological vowel pairs (/*i*, *i:*, *a*, *a:*, *u*, *u:*/). In various CA dialects, however, additional vowels exist. We focus here on the CAI vowel system, which includes five short and five long vowels: /*i*, *i:*, *e*, *e:*, *a*, *a:*, *o*, *o:*, *u*, *u:*/ (Blanc, 1953; Levin, 1994; Tsukada, 2009).

Descriptive phonological studies report that the phonemic vowels /i, a, u/ in CAI usually have several allophones. In CAI, for example (Palva, 1965), the phoneme /i/ has [ɪ, ə], or [e] as an allophone in the environment of front consonants (e.g., [bint∼bɪnt∼bənt] "girl, daughter"), and /u/ has [o] as an allophone in a velar, laryngeal, pharyngeal or pharyngealized consonant environment (e.g., [quds∼qods] "holiness"). A short [i, ə] or [e], as well as [u, o] or [a] may also occur as an epenthetic to dissolve various consonant clusters according to the (usually stressed) adjacent vowel (e.g., [nahr∼nahar] "river," ʕumr ∼ʕomor "life time, age"). The vowels /a/ and /a:/ have back ([a, a:] and front ([æ, æ:]) allophones occurring in the adjacency of back or front consonants, respectively (e.g., [qa:l] "he said," [næ:s] "people"). In addition, in certain morphological and phonetic environments, /a/ could be raised to [e] or [i] (e.g., /sane ∼ sini/ "year"). Short /e/ is not only epenthetic in CAI, but also phonemic (e.g., [læk] "for you" masculine singular vs [lek] "for you" feminine singular, or [laħme] "a piece of meat" vs [laħmi] "my flesh"). Similarly, minimal pairs exist for the vowels /u/ and /o/, e.g., /katabu/ "they wrote" vs /katabo/ "he wrote it," or /ʃufto/ "I saw him" vs /ʃofto/ "his look, how he looks like."

The long vowels /i:, a:, u:/ are less variable; though as noted, /a:/ has front and back allophones. Long /e:, o:/ in CAI are not considered original phonemes, as they, respectively, reflect the monophthongized diphthongs /ai, au/ (which exist in MSA and in certain CA dialects such as Lebanese CA), as in, e.g., MSA /bait/ ∼ CAI /be:t/ "house," MSA /jaum/∼ CAI /jo:m/ "day"), or vowels in borrowed foreign words (e.g., /talafo:n/ "telephone," /ne:rs/ "nurse"). Furthermore, in some CAI dialects (and elsewhere), word final /i/ may be replaced with the diphthong /ai/ [e.g., /ʔana babki/ > /ʔana babkai/ "I am crying," /baddak ʔiʃi/ > /baddak ʔiʃai/ "do you (male singular) want anything?" (Blanc, 1953)].

C. CAI acoustics

Acoustic studies of the Shaami dialects in general, are still fewer than general phonological ones, though this research field has been developing since the second half of the 20th century (see e.g., Obrecht, 1968; Card, 1983; Newman and Verhoeven, 2002; Barkat-Defradas *et al.*, 2004; Bakalla, 2008; Al-Tamimi and Khattab, 2011; Heselwood *et al.*, 2011; Zawaydeh and de Jong, 2011). These and many other studies focused on characteristic features of CA consonants and vowels, such as pharyngealized/uvularized (or "emphatic") and laryngeal and pharyngeal consonants, consonantal gemination, nasalization, vowel systems, prosody, etc.

Studies which have analyzed CA vowels of the Eastern dialects group, discuss inter-dialect similarities and differences [e.g., Lebanese CA (Obrecht, 1968), Palestinian dialects (Saadah, 2011), Jordanian and Moroccan Arabic (Al-Tamimi and Barkat-Defradas, 2003), CA dialects and other Semitic languages (Rosenhouse, 2002), and several Arabic dialects (Newman and Verhoeven, 2002)]. However, relatively few studies have examined the acoustic characteristics of the Arabic vowel systems. Furthermore, these studies focused on specific and limited aspects. Al-Tamimi and Barkat-Defradas (2003), for example, reported a more centralized vowel space in Moroccan Arabic than in Jordanian Arabic. They also reported that, in general, the vowel space was more centralized for short vowels than for long ones, and more centralized for men than for women. In another study, Saadah (2011) examined three short and long vowel pairs /i-i:, u-u:, a-a:/ (but not /e-e:/ and /o-o:/) in non-pharyngeal and pharyngeal environments in Palestinian Arabic. She reported that the /i - u/ pair and the /i: - u:/ pair had very close F1 values, showing that height was similar for vowels with front and back tongue position. As to F1 of the pair /a - a:/, Saadah (2011) shows somewhat lower Bark values for F1 of short /a/ than for long /a:/. Regarding F2, Saadah (2011) found that long /i:/ was more fronted than /i/, and /u:/ was more backed than /u/, which indicated that longer vowels were produced at the periphery of the vowel space while shorter vowels occupied more centralized positions. The low vowels /a, a:/ were found to have identical F2 values. She therefore suggested that short vowels have a significantly smaller vowel space than the long vowels.

1. Interaction between different acoustic properties

As mentioned above, Arabic in general and CAI in particular distinguish between short and long vowels. This property is common to many other languages, among them Thai (Abramson and Ren, 1990) Danish, Finnish, Japanese (Ladefoged and Johnson, 2011) and even dialects of French (Grosjean *et al.*, 2007). It is therefore of great interest to measure durations of short and long vowels and carry out a detailed comparison between them. Moreover, initial studies in Arabic mentioned above, as well as several studies of other languages, have shown that temporal and spectral vowel properties may interact. A study in Thai (Abramson and Ren, 1990) shows that for some vowels pairs (such as /e: e/, /i: i/) the short vowel is more centralized than the long vowel, whereas for the pair /a: a/ no difference is observed. In Swedish, on the other hand (Fant, 1983), it appears that in some short vowels F1 is raised in comparison to the long counterparts. There is some speculation as to whether this type of linkage is due to physiological constraints, or whether it is perceptually necessary, as the short/long cue might not be sufficient on its own for discriminating between short and long vowels. More recent perceptual experiments have been looking into this (Hadding-Koch and Abramson, 2008), however, perceptual issues are not the focus of the current study.

In addition to the interaction between duration and spectrum, which is specific to quantity languages, previous studies have also found interaction between different vowels and fundamental frequency. This has been found both in quantity languages such as Danish and in languages which do not have a length distinction, such as Brazilian and European Portuguese and English (Petersen, 1978; Escudero *et al.*, 2009; Whalen and Levitt, 1995). Generally, vowels with higher tongue position were found to have higher F0, and vowels with back tongue position were found to have higher F0 also. It is therefore of interest to examine whether such phenomena occur in CAI also.

D. Objectives

The studies mentioned above provide some preliminary observations on the Arabic vowel systems. However they targeted specific issues, without providing a comprehensive picture of the complete vowel system of any region, nor did they examine the dialects within such a region.

Therefore, the primary objective of our study was to explore in depth the acoustics of the CAI vowel systems, through the comparison of two of the major local dialects in Israel. The main research questions we set out to answer were as follows:

(1) What are the acoustic properties (specifically, F0, F1, F2, and duration) of vowels in CAI and how do they interact?
(2) Are there differences between the vowel systems of the two dialects?
(3) What are the differences between long and short vowels in each dialect?

II. METHOD

A. Participants

Our study focuses on the acoustic structure of the vowel system of two CAI dialects. One is the dialect spoken in the region of Kafr Qasem, Kfar Bara, and Jaljulia, in the southern part of the "Triangle" (*Muthallath*, in Arabic) in the center of the country, which we term the Muthallath Dialect (MD) (Jastrow, 2004). The second is the dialect spoken in the region of Majd Al-Kurum located in the Galilee region in the north of Israel, which we term the Galilean Dialect (GD). All of these locations are mainly populated by Muslims and were originally villages. During the 20th century, their populations increased so that now they are officially towns, but their dialects are still considered rural.

TABLE I. Average age and academic education (in years) of the two groups (SD values are in parenthesis).

Dialect	Gender	Mean age (years)	Mean academic education (years)
MD	Men	22.95 (2.48)	2.95
	Women	23.35 (2.57)	3.45
	Entire group	23.1 (2.53)	3.2
GD	Men	24.75 (2.8)	2.8
	Women	24.28 (2.57)	2.57
	Entire group	24.63 (2.68)	2.68

Eighty participants were chosen so as to match geographical, social, and communal (religion) criteria. Forty were native speakers of MD and 40 were native speakers of GD. Each group consisted of 20 men and 20 women. All participants were natives of the towns listed above; all were Muslims, to prevent inter-community dialect differences that may exist between different faith community speakers (Blanc, 1964); and all were students or graduates of an academic institute, with no reported hearing or speech problems. It should be noted that both Arabic and Hebrew are official languages in Israel, Hebrew being the dominant one. All Arabic speakers in Israel acquire Hebrew at school, which they continue to use in their academic studies as well as in their daily communication with Hebrew speakers. Therefore, the contemporary variants of CAI are, by nature, dialects spoken by native Arabic speakers who are also exposed to Hebrew.

Table I presents participants' average age and duration of post-secondary education (in years). After receiving the approval of our institution's ethical committee, and before the recordings, all participants completed an informed consent form, and a short questionnaire regarding age, home locations, native language, and education.

B. Test material

This study focused on vowels in non-pharyngealized environments. This was deemed desirable because pharyngealization usually affects adjacent vowels by lowering F2 and raising F1 (e.g., Obrecht, 1968; Abudalbuh, 2011).

The five short /i, e, a, o, u/ and five long vowels /i:, e:, a:, o: u:/ of the two dialects were studied. For each of the two dialects, the test material comprised three real-word lists, i.e., three different words per vowel (see complete word lists in the Appendix), altogether 30 words per dialect. The lists included 24 CVC monosyllabic words, and six disyllabic words in the CVCVC pattern. These six words were necessary to provide examples of short /i /or /u/ vowels, which do not occur in monosyllabic CVC words in the studied Arabic dialects.[3] Only the stressed V1 was measured in these words, because V2 is unstressed either due to the morphological pattern (e.g., in /sufon/ "ships," or /mudon/ "towns") or due to phonetic factors that require inserting it as an epenthetic vowel (as in, e.g., /ʕidʒer/ "leg" or /furon/ "oven").

To enable participants to read the words fluently and without hesitation, only words that would be intelligible and legible even without vowel marks, were selected. Furthermore, the sentences were written as they would be pronounced in CAI, and not necessarily according to the MSA grammar rules.[4] Writing CA is somewhat contrary to conventions, but CA is currently written in Arabic for many goals including theater plays, realistic novels, jokes, personal letters, etc. (e.g., Rosenbaum, 2004). Therefore, this method was appropriate for this task.

The test words were inserted in a carrier sentence: "I am reading the word…, which is written on the piece of paper" (in Arabic: /ʔana b-aqra l-kilme…. el-maktu:be ʕala l-war-aqa/ انا بقرا الكلمه _____ المكتوبه على الورقه), which in Arabic has seven words. The central position of the test word was intended to prevent phrase final effects of lengthened vowels (see, e.g., Zawaydeh and de Jong, 2011). This procedure yielded 1200 utterances (30 test words × 40 participants) per dialect, and 2400 utterances altogether.

C. Procedure

Before recording, each participant received an example of a test sentence and read the test words, to avoid reading errors. Participants were also instructed to read the sentences naturally, at their most comfortable speech rate, without any special stress, as they would say them in their CA dialect. Each participant was recorded separately in a quiet room. The lists were presented in a random order. In case of an error, the participant was allowed to repeat and correct the sentence.

All recordings were carried out on a personal computer, using a head-mounted Audio Technica AT-892 microphone and an external Centrance Micport Pro USB soundcard. Recordings were performed at a sampling rate of 44 100 Hz, 16 bits per sample. All recordings were annotated manually by two pairs of phonetically experienced research assistants. Each research assistant annotated recordings of his/her dialect only. Annotation was performed, using Praat software (Boersma, 2001). Marking the beginnings and endings of each target vowel was performed based on a combined inspection of both a spectrogram and the speech waveform. Duration data was extracted from these annotations.

F0 analysis was carried out using Praat, and then reviewed visually. Erroneous values, octave jumps, etc. were corrected manually. The final F0 value for each vowel was taken as the mean F0 over the middle 30 ms. Custom software, written in MATLAB (2010a, The Mathworks, Natick, MA) specifically for this purpose was used to perform supervised calculation of the first two formants, on the central 30 ms of each target vowel. Formant calculation was based on the LPC algorithm (Rabiner and Schafer, 1978) with pre-emphasis at 50 Hz. Relying on fully automated formant calculation is notoriously problematic (e.g., Escudero *et al.*, 2009). To eliminate calculation errors, the sound files were all downsampled to 8 kHz prior to analysis, then LPC was applied with a user-specified LPC model order. In the interest of consistency, formants for each vowel were calculated at the highest model order achievable without "formant splitting," i.e., without obtaining two resonances in the LPC model representing a single formant. The program was implemented in a convenient Graphical User Interface (GUI), which enabled an experienced phonetician to scan manually through the 2400 tokens in several hours.

III. RESULTS

In this section, we present, first, descriptive statistics of formant values, duration values, and fundamental frequency. This is followed by inferential statistics, examining the vowel features of the two CAI dialects, separately and in comparison with each other.

A. Descriptive statistics

The variables examined here were F0, F1, F2, and duration. Mean values and SDs are presented in Table II, separately for men and women, and for the two dialects. Figure 1 shows scatterplots and error ellipses of the F1-F2 vowel

TABLE II. Averages and SDs (in parentheses) for Duration (ms), F0, F1, F2 (Hertz) for Males and Females in both dialects (F-Female, M-Male, Dur-duration).

			/i/	/i:/	/e/	/e:/	/a/	/a:/	/o/	/o:/	/u/	/u:/
MD	Dur.	F	58 (8.3)	114 (20.2)	69 (12.5)	125 (24.5)	74 (12.7)	136 (21.8)	67 (12.9)	127 (27.4)	55 (8)	116 (25.2)
		M	63 (30.9)	111 (22.6)	66 (14)	118 (22.7)	67 (13.1)	123 (25.6)	63 (12.4)	116 (24.2)	56 (9.5)	105 (21.9)
	F0	F	242 (27.2)	245 (24.2)	246 (31.6)	233 (32)	240 (24.2)	232 (26.1)	246 (27.9)	237 (28.4)	247 (26.1)	247 (27.7)
		M	144 (22.6)	146 (22.7)	147 (21.8)	141 (23.1)	144 (19.9)	141 (19.9)	146 (22.1)	145 (21.5)	143 (20.7)	147 (26.2)
	F1	F	458 (59.9)	456 (41.3)	506 (91.7)	579 (66.1)	696 (70.1)	770 (83.6)	576 (86.3)	588 (80.3)	498 (68)	456 (60.3)
		M	385 (45.4)	375 (33.4)	397 (25.3)	456 (46.4)	551 (40.1)	591 (32.1)	462 (33.7)	479 (43.2)	418 (46)	391 (57.4)
	F2	F	2068 (158.6)	2345 (201.4)	2004 (156.6)	2116 (169)	1621 (97.5)	1541 (148.5)	1320 (137.5)	1192 (135.4)	1335 (114.5)	1119 (162.6)
		M	1713 (138.6)	1931 (178.2)	1765 (135.9)	1779 (166.5)	1360 (69.4)	1296 (72.2)	1092 (115.1)	1024 (70.2)	1096 (71.4)	1023 (184.6)
GD	Dur.	F	53 (10.5)	111 (26.3)	72 (11.4)	109 (20.9)	70 (14.4)	114 (24.2)	65 (11.9)	114 (12.7)	47 (9.1)	119 (26)
		M	48 (7.8)	110 (33.5)	62 (19.7)	105 (29.7)	63 (18.6)	121 (25.6)	62 (14.6)	113 (28.5)	47 (9.6)	104 (28.5)
	F0	F	219 (28.1)	223 (27.9)	221 (23)	215 (23.7)	215 (24.4)	213 (23.3)	216 (28.8)	211 (25.8)	227 (28.5)	226 (29.2)
		M	130 (17.3)	131 (16.8)	131 (19.3)	129 (16.3)	128 (16.7)	127 (16.5)	132 (18.5)	130 (16.2)	133 (18.1)	134 (17.4)
	F1	F	443 (39.7)	411 (48)	541 (77.6)	533 (64.5)	697 (62.3)	728 (72.3)	582 (56.1)	558 (83.8)	496 (47.3)	444 (41.9)
		M	397 (33.7)	361 (29.9)	480 (34.4)	477 (39)	568 (46)	597 (48.4)	497 (40)	481 (40.3)	447 (30.4)	382 (29.7)
	F2	F	2180 (163)	2416 (200.3)	2075 (96.5)	2209 (129.4)	1523 (83)	1593 (67.9)	1346 (83.1)	1163 (123.5)	1405 (75.3)	1086 (204.3)
		M	1765 (135.8)	2013 (145.7)	1697 (156.6)	1754 (127)	1253 (83.1)	1270 (76.8)	1134 (117)	1043 (123.3)	1183 (166)	965 (119)

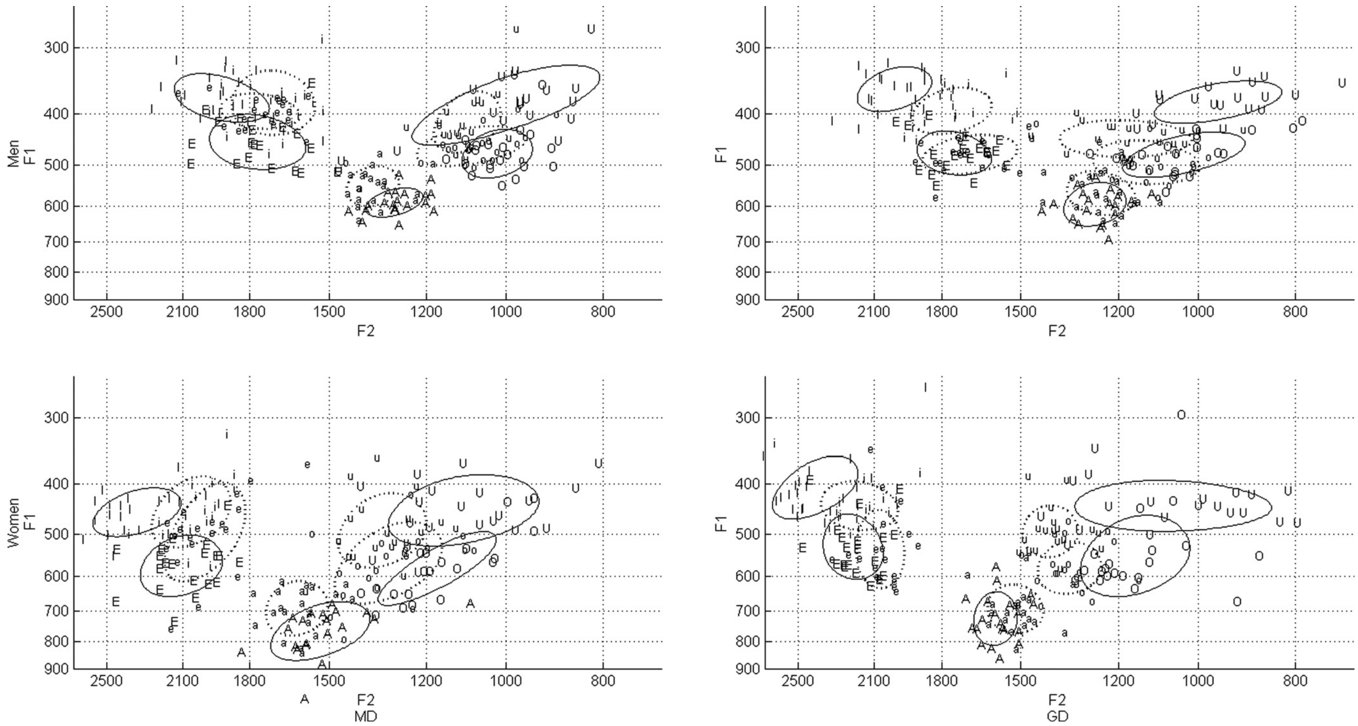

FIG. 1. Scatterplots of F1 vs F2 for short (/i e a o u/) and long (/i: e: a: o: u:/) vowels. Top graphs are for men, bottom are for women; left graphs are MD, right are GD. Note that for clarity, in this graph only, the long vowels are denoted by capitals (i.e., /A/ instead of /a:/, etc.). Ellipses denote a confidence interval of 0.05—solid ellipses are for long vowels, dotted ellipses are for short vowels.

space for both dialects and both genders. Figure 2 shows the vowel spaces for each gender and dialect, based on the mean values in Table II. Each set of five short and five long vowels is plotted as a separate polygon.

Initial observations can be made from Figs. 1 and 2. In both dialects, the short vowels occupy a smaller vowel space than the long vowels, suggesting that duration is not the sole factor distinguishing between them. However, this effect is more pronounced for certain vowels than others. For example, /i/ appears to have a very similar F1 for long and short vowels in MD but not in GD. This will be examined further below. In addition, there appears to be a considerable similarity between the two dialects in the long vowels, but less so in the short vowels.

In the following sections, we perform exploratory statistics on the above variables, followed by additional analyses, aimed to answer the research questions.

B. First formant

1. Exploratory analysis of F1

An exploratory analysis was conducted by performing an analysis of variance (ANOVA) with-repeated-measures, in which Vowel (/i, e, a, o, u/) and Length (long/short) were defined as the within-subject (repeated) factors, and Gender and Dialect as the between-subject factors. Clearly, a significant main effect would be expected for Vowel and Gender. Though such a main effect is not particularly informative, its lack would indicate some kind of methodological error.

Indeed, highly significant main effects were found for Vowel [$F_{(4,300)} = 653.03$, $p < 0.001$], and for Gender [$F_{(1,75)} = 90.03$; $p < 0.001$]. No significant main effects were found for Length or Dialect ($p > 0.05$). Significant interactions were found for Vowel*Length [$F_{(4,300)} = 55.84$; $p < 0.001$], Vowel*Gender [$F_{(4,300)} = 5.58$; $p < 0.001$], Vowel*Dialect [$F_{(4,300)} = 5.63$; $p < 0.001$], and Length*Dialect [$F_{(1,75)} = 41.85$; $p < 0.001$]. Length*Gender interaction was not significant ($p > 0.05$). A significant three-way interaction was also found for Vowel*Length*Dialect [$F_{(4,300)} = 4.04$; $p = 0.003$]. Despite the lack of main effect for Length or Dialect, the significant interactions of other factors with these two warranted further statistical analysis.

Contrast analyses were performed between all adjacent vowels, with a Bonferroni correction for multiple comparisons ($\alpha = 0.01$). Significant contrasts were found for all adjacent vowel pairs (/i-e/ /e-a/ /a-o/ /o-u/ and /u-i/) ($p < 0.01$). This result also motivated more targeted analysis, as presented below.

2. Comparing F1 for short and long vowels

Because of the lack of main effect for Length, along with the significant Vowel*Length interaction, we set out to examine in which vowel categories a difference in F1 between the short and long vowel could be found. In light of the significant Vowel*Gender and Vowel*Dialect interactions, five t-tests were used to compare F1 of short and long versions of each vowel. This was carried out separately for every combination of Gender and Dialect. A Bonferroni correction for multiple comparisons was applied ($\alpha = 0.01$). Results are illustrated in Fig. 3. The most prominent results (i.e., that are consistently significant for both men and women of the same dialect) are that the pair /i-i:/ has the same F1 value only in the MD dialect, whereas the pair /e-e:/

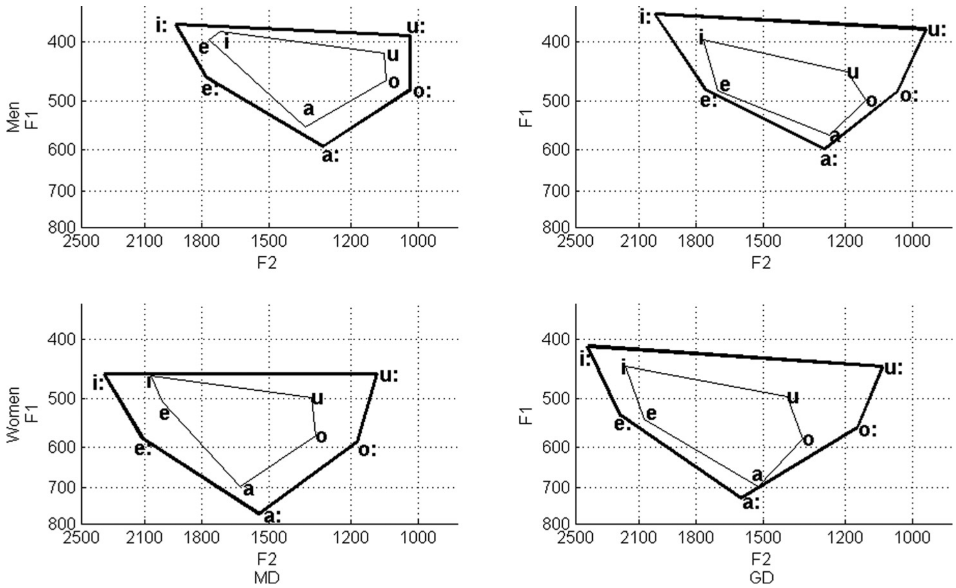

FIG. 2. Vowel space plots of F1 vs F2 for short (/i e a o u/) and long (/i: e: a: o: u:/) vowels. Top graphs are for men, bottom graphs are for women; left graphs are MD, right are GD.

has the same F1 value only in the GD dialect. In contrast, the /o-o:/ pair has the same F1 value in both dialects. In both dialects, the /u-u:/ pair has different F1 values, whereas the /a-a:/ pair has different values for both men and women only in MD. Figure 3 also demonstrates that the overall F1 patterns are similar for men and women of the same dialect.

3. Comparing F1 across dialects

Because of the lack of main effect for Dialect in the exploratory analysis, along with the significant Length*Dialect interaction, we examined in which vowel categories a difference in F1 between the two dialects could be found. Two separate ANOVAs were performed, one for long and one for short vowels, with Dialect and Gender as between-subject factors, and Vowel as the within-subject factor. For long vowels, no significant main effect was found for Dialect [$F_{(1,76)} = 2.917$, $p = 0.09$]. For short vowels, however, a significant main effect for Dialect was found [$F_{(1,76)} = 5.525$, $p = 0.021$]. This confirms that the two dialects have comparable long vowel systems, but different short-vowel systems.

4. F1 categories

F1 values are often associated with the phonological description of vowel height, in which several vowels usually fall into common categories (Ladefoged and Johnson, 2011). Although the present study examined *acoustic* properties of vowels, this section uses phonological labels (high/mid/low) when referring to F1 categories. Figure 1 suggests the existence of three vowel-height categories for long vowels, in which /i:/ and /u:/ are high, /e:/ and /o:/ are mid, and /a:/ is

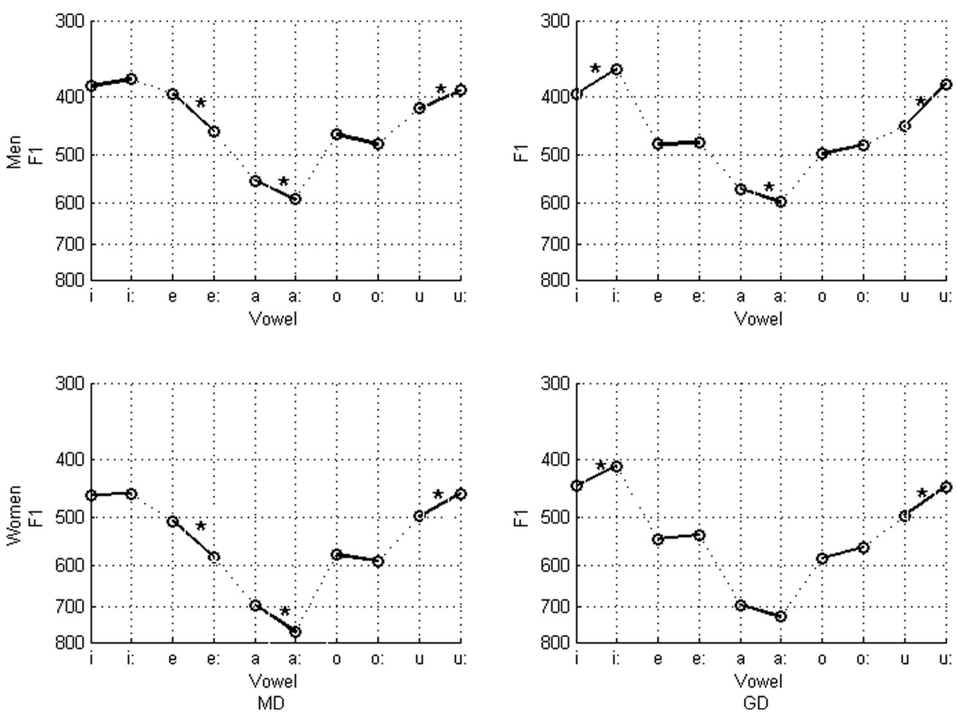

FIG. 3. F1 values for all short (/i e a o u/) and long (/i: e: a: o: u:/) vowels, Top graphs are for men, bottom are for women; left graphs are MD, right are GD (*– $p < 0.01$). Note the descending *y* axis, as in Figs. 1 and 2.

low. This can be observed for both dialects, for men and women alike. This systematic categorization, however, is not evident for short vowels. The exploratory analysis of F1 revealed significant interactions of Length*Dialect, Vowel*Length and Vowel*Length*Dialect. Therefore, to learn whether the data supports the existence of three distinct height categories, we performed eight separate ANOVAs, one for each combination of Gender, Length, and Dialect, with Vowel being the only within-subject factor. All ANOVAs were statistically significant [$F_{(4,76)} > 60.00$, $p < 0.001$]. Following each ANOVA, eight contrasts were examined: The contrasts between the two high vowels /i, u/, between the two mid vowels /e, o/, the contrasts between each of the two high and two mid vowels, and the contrasts between the two mid vowels and the low vowel /a/. After applying the Bonferroni correction for multiple comparisons, significance level for this procedure was set at $\alpha = 0.00625$. This is illustrated in Fig. 4 and presented in detail in Table III.

Several patterns emerge as shown in the following:

(1) In all cases, the mid vowels (/e/, /e:/, /o/, /o:/) were significantly higher than the corresponding low vowels (/a/, /a:/).
(2) There was no significant height difference between the two long mid vowels (/e:/, /o:/) for both genders and both dialects.
(3) There was no significant height difference between the two long high vowels (/i:/, /u:/) in the Muthallath dialect, for men and women alike. However, these vowels' height was significantly different ($p < 0.001$) for both men and women in the Galilee dialect, with /i:/ being higher than /u:/.

C. Second formant

1. Exploratory analysis of F2

Similar to F1, an exploratory analysis on F2 was conducted by performing an ANOVA-with-repeated-measures, in which Vowel (/i, e, a, o, u/) and Length (long/short) were defined as the within-subject (repeated) factors, and Gender and Dialect as the between-subject factors. Significant main effects were found for Vowel [$F_{(4,300)} = 1437.86$, $p < 0.001$], Gender [$F_{(1,75)} = 200.65$; $p < 0.001$] and Length [$F_{(1,75)} = 31.23$; $p < 0.001$]. No significant main effect was found for Dialect ($p > 0.05$). Significant interactions were found for Vowel*Length [$F_{(4,300)} = 122.38$; $p < 0.001$], Vowel*Gender [$F_{(4,300)} = 3.07$; $p = 0.017$], Vowel*Dialect [$F_{(4,300)} = 3.05$; $p = 0.017$], and marginally significant for Length*Gender [$F_{(1,75)} = 4.01$; $p = 0.049$]. No significant Length*Dialect interaction was found ($p > 0.05$). Compared to the exploratory analysis of F1, an additional main effect was found for Length, indicating that on average - F2 is more affected by length than F1. Here too, the lack of main effect for Dialect, along with the multitude of interactions, motivated a more detailed analysis.

Contrast analyses between the five vowel categories were performed between all adjacent vowels, with a Bonferroni correction for multiple comparisons ($\alpha = 0.0125$). Similarly to F1, significant contrasts were found for all adjacent vowel pairs (/i-e/ /e-a/ /a-o/ /o-u/) ($p < 0.001$). Note that when considering F2, in contrast to F1, the /i-u/ pair is not to be considered adjacent.

2. Comparing F2 for short and long vowels across dialects

Because of the main effect for Length, along with the significant Vowel*Length interaction, we examined in which vowel categories a difference in F2 between the short and long vowel could be found. Because of the Vowel*Gender and Vowel*Dialect interactions, this was performed separately for each combination of Gender and Dialect. Hence five *t*-tests were applied for each such combination, comparing F2 of short and long versions of each vowel, applying a Bonferroni correction ($\alpha = 0.01$). Results are illustrated in Fig. 5. The Vowel*Gender interaction shown above can be attributed to the fact that women exhibited a difference between /e/ and /e:/, whereas men did not. The most prominent results (i.e., those that are consistently significant for both men and women) are that only the pair /a a:/ has the same F2. In this case, as opposed to F1, Fig. 5 shows that the overall F2 patterns are similar across Gender and Dialect.

3. F2 categories

A major factor influencing F2 is tongue position, though it is influenced by other factors also, such as lip rounding. Its values are often associated with the phonological description of tongue position, in which several vowels usually fall into common categories (Ladefoged and Johnson, 2011) Similarly to our description of results for F1, this section uses phonological labels (front/mid/back tongue) when referring to F2 categories. Figure 1 suggests that there are at least three categories of tongue position for long vowels, in which /i:/ and /e:/ are front, /a:/ is central, and /o:/ and /u:/ are back. This can be observed in both dialects, for men and women alike. This systematic categorization is similar for short vowels. Therefore, in order to learn whether data support the existence of three distinct tongue-position categories, we performed four ANOVAs similarly to the previous analyses

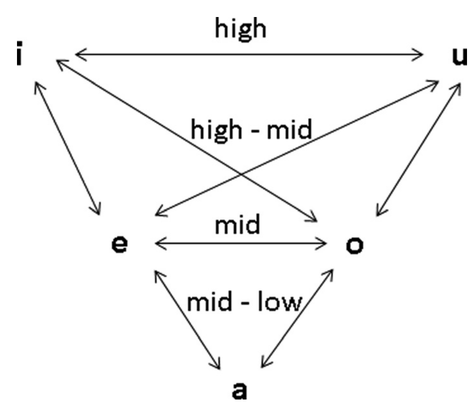

FIG. 4. A graphical description of the comparisons performed to determine height categories.

TABLE III. p values of contrasts for the ANOVAs for vowel heights.

		Long				Short			
		Muthallath		Galilee		Muthallath		Galilee	
		Men	Women	Men	Women	Men	Women	Men	Women
High	i-u	0.252	0.833	$<0.001^*$	0.001^*	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$
Mid	e-o	0.011	0.631	0.455	0.086	$<0.001^*$	$<0.001^*$	0.061	0.002^*
High to mid	i-o	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$
	i-e	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	0.134	0.001^*	$<0.001^*$	$<0.001^*$
	u-o	$<0.001^*$	0.001^*	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$
	u-e	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	0.067	0.72	$<0.001^*$	0.021
Mid to low	o-a	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$
	e-a	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$	$<0.001^*$

$^*p < 0.00625$.

for F1: One ANOVA for each combination of Gender and Length, with Vowel as the only within-subject factor. This was followed by four vowel contrasts: /i-e, e-a, a-o, o-u/. Main effects for Vowel were significant in all ANOVAs [$F_{(4,156)} > 330$, $p < 0.001$]. A Bonferroni correction for multiple comparisons was applied, with a significance level set at $p < 0.0125$. All contrasts between adjacent vowels (/i-e, e-a, a-o, o-u/) were statistically significant, except for the /i-e/ contrast for the short vowels, which was non-significant for men ($p = 0.60$), and borderline for women ($p = 0.011$). Several patterns emerged as described in the following:

(1) The contrast pattern is nearly identical for men and women.
(2) For short vowels, four distinct tongue-position categories emerged: front (/i, e/), mid (/a/), and separate categories for each of the back vowels (/o, u/).
(3) For long vowels, Five distinct tongue-position categories were found, one for each of the five long vowels.

D. Duration

An exploratory analysis was conducted by performing ANOVA-with-repeated-measures, in which Vowel (/i, e, a, o, u/) and Length (long/short) were defined as the within-subject (repeated) factors, and Gender and Dialect as the between-subject factors. Significant main effects were found for Vowel [$F_{(4,284)} = 41.4$, $p < 0.001$] and for Length [$F_{(1,284)} = 905.4$; $p < 0.001$]. Thus, as expected, long vowels were significantly longer than the short ones.

No significant main effects were found for Gender or Dialect ($p > 0.05$). A significant interaction was found only for Vowel*Length [$F_{(4,284)} = 7.1$; $p < 0.001$]. We can thus conclude that while the long/short distinction is consistent across dialectal and gender boundaries, this difference varies in magnitude among the five vowel pairs. Table IV, therefore, presents mean values and standard deviation of durations, averaged over Gender and Dialect. These results are further illustrated in Fig. 6(a).

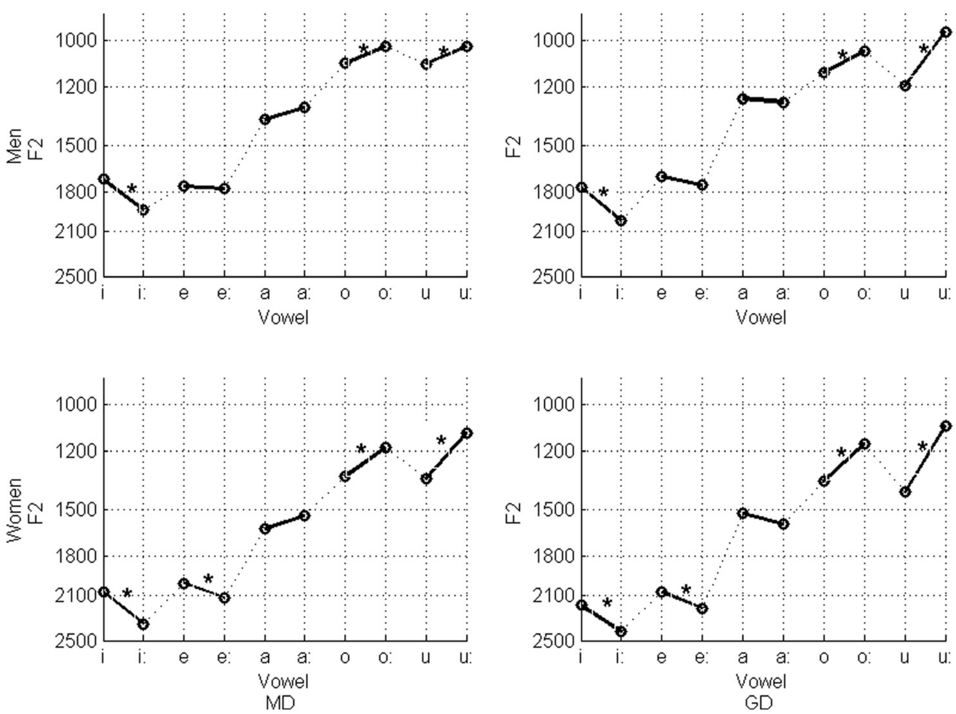

FIG. 5. F2 for all short (/i e a o u/) and long (/i: e: a: o: u:/) vowels, Top graphs are for men, bottom are for women; left graphs are MD, right are GD ($* - p < 0.01$). Note the descending y-axis, consistent with the descending x-axis in Figs. 1 and 2.

TABLE IV. Mean Duration and Standard Deviation (in parentheses) of the ten vowels.

	/i/	/e/	/a/	/o/	/u/
Short [ms]	55 (18.0)	67 (15.0)	68 (15.2)	64 (12.9)	51 (9.8)
Long [ms]	111 (25.7)	114 (25.4)	124 (25.1)	117 (24.1)	111 (25.8)
Ratio	2.10 (0.53)	1.72 (0.32)	1.84 (0.31)	1.84 (0.30)	2.21 (0.54)

Following the exploratory analysis, we conducted two separate ANOVA-with-repeated-measures over the short and long vowels separately. Because of the lack of main effect for Dialect and Gender in the exploratory analysis, these factors were not considered further. A main effect for Duration was found for both short vowels [$F_{(4,74)} = 24.17$; $p < 0.001$] and long vowels [$F_{(4,74)} = 12.95$; $p < 0.001$].

For short vowels, contrast analysis with Bonferroni correction revealed that durations of the two high vowels /i, u/ were significantly shorter than those of the lower vowels /e, a, o/. For long vowels, contrast analysis with Bonferroni correction revealed that the duration of the low vowel /a:/ was significantly longer than those of all other vowels. In addition, the duration of /o:/ was significantly longer than the duration of /u:/. In summary, lower vowels in each category (short and long) tended to be longer than the higher vowels.

Beyond absolute duration values, the ratio of long to short duration was calculated, to examine whether it provides more uniform results across the different vowels. As shown in Fig. 6(b), duration ratios of the lower vowel categories /e, a, o/ were smaller than the duration ratios of the high vowels /i, u/.

To summarize, results illustrated in Fig. 6 and their corresponding statistical analyses confirm that phonologically long vowels are indeed longer in duration than the phonologically short vowels. Specifically, the long-short ratio ranged between 1.7 and 2.2.

E. Fundamental frequency

Previous studies (e.g., Escudero *et al.*, 2009) reported various effects of Vowel and Dialect on F0, which were therefore examined here also. Since F0 is perceived on an approximately logarithmic scale, all statistics related to F0 were performed on log(F0) (Escudero *et al.*, 2009). ANOVA with repeated measures was performed, where Vowel and Length were defined as the within-subject factors, and Gender and Dialect were defined as the between-subject factors. Significant main effects were found for Vowel [$F_{(4,288)} = 17.9$; $p < 0.001$]. In addition, long vowels had higher log(F0) than short vowels [$F_{(1,72)} = 11.9$; $p = 0.001$]; and women had higher log(F0) than men [$F_{(1,72)} = 319.2$; $p < 0.001$]. Furthermore, log(F0) was significantly higher for MD than for GD [$F_{(1,72)} = 12.1$; $p = 0.001$]. A significant Vowel*Length interaction [$F_{(4,288)} = 12.5$; $p < 0.001$] was found, as well as a Length*Gender interaction [$F_{(1,72)} = 5.2$; $p = 0.026$].

It should be noted that while the majority of these statistically significant results follow the expected pattern, the fact that the mean F0 was higher in a specific dialect (for both genders) was not expected.

Contrast analysis with Bonferroni correction between adjacent vowels revealed an overall significant difference between the vowel categories /e, e:/ and /a, a:/, and between /u, u:/ and /o, o:/. This denotes that high vowels (/i, i:/ and /u, u:) also had higher F0 than the low vowel /a, a:/.

Figure 7 presents a full breakdown of F0 by Gender, Dialect, Length, and Vowel. No clear systematic pattern is observed, beyond those reported above.

IV. DISCUSSION

Relatively few studies have addressed the vowel system of Arabic, in general, and CAI in particular. Therefore, there is little previous literature to which our results can be compared.

However, the fact that two different dialects were examined here enables us to underline what appear to be the more universal aspects of CA as spoken in Israel, vs those that appear to be more dialect-specific. The main findings of the present study can be summarized as follows: (a) CAI has five basic vowels, with a long and short version of each; (b) The five long vowels are clearly distinct, significantly different from each other in either F1, F2, or both, in a similar manner in both dialects (MD and GD); (c) Short vowels are approximately two times shorter in duration and more

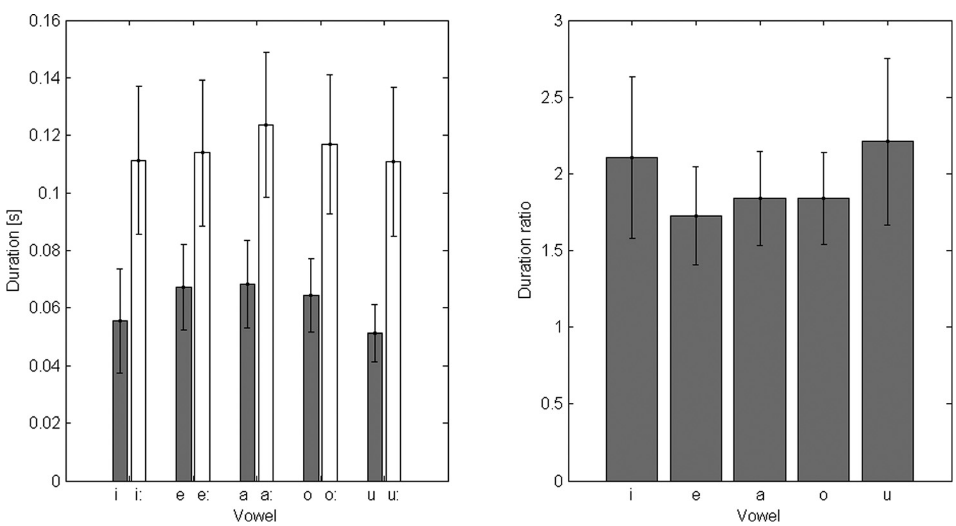

FIG. 6. (a) Mean duration and STD of all short (/i e a o u/) and long (/i: e: a: o: u:/) vowels. Gray bars represent short vowels, and white bars represent long vowels; (b) Long/short duration ratios and STD of the five vowel pairs (/i-i: e-e: a-a: o-o: u-u:/).

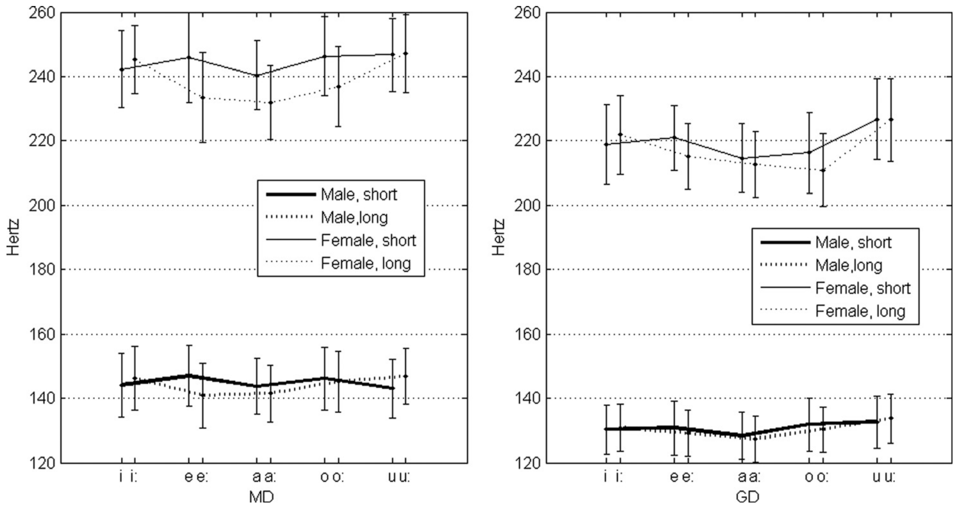

FIG. 7. Mean F0 and 95% confidence interval error-bars for all short (/i e a o u/) and long (/i: e: a: o: u:/) vowels in both dialects. (a) MD, (b) GD.

centralized in the F1-F2 plane than the long vowels; and (d) Short vowels' characteristics are more dependent on the specific dialect, and in some cases articulatorily adjacent vowels appear to merge (e.g., /i/ and /e/, in MD). These findings are discussed below in further detail.

A. Long vowels

Long vowels in both dialects were found to be very similar. Generally speaking, the five long vowels of CAI comprise a typical five vowel system, similar to that observed in other languages, such as Hebrew (Most *et al.*, 2000) or Spanish (Delattre, 1969; Ladefoged and Johnson, 2011). This vowel space is spanned by the three corner vowels /i:/, /a:/ and /u:/, in addition to the two vowels /e:/ and /o:/. Specific properties of this vowel space were determined.

1. Height

Visual inspection of these vowels, as displayed in Fig. 2, initially suggested the existence of three distinct height categories for the long vowels. These include two high vowels (/i:/ and /u:/), two medium-height vowels (/e:/ and /o:/), and a single low vowel (/a:/). This separation between three height categories was corroborated, and found consistent for both dialects and Genders. Nonetheless, in GD, the front vowel /i:/ is significantly higher than the back vowel /u:/. This demonstrates that, within this dialect, vowel height categorization is performed differently for front and back vowels. This finding is reminiscent of other vowel systems, such as Portuguese (Escudero *et al.*, 2009), for example.

2. Front/back tongue position

Five distinct categories of tongue position were found, one for each of the five long vowels: front (/i:/), mid-front (/e:/), mid-back (/a:/), and mid-back (/o:/) and back (/u:/). This categorization of tongue position is also consistent for both dialects and genders.

3. Duration

Within the five long vowels, duration was affected by vowel height, such that lower vowels were typically produced with longer duration. This is in agreement with similar reports on other languages (Most *et al.*, 2000).

4. F0

As expected, women's F0, in both dialects was approximately an octave higher than men's F0. Long vowels had lower F0 than short vowels, and the low vowels /a, a:/ had lower F0 than the high vowels /i, i: u, u:/, as documented for other languages (e.g., Most *et al.*, 2000; Peterson and Barney, 1952).

Surprisingly, F0 values were found to be higher for MD speakers, in general, than for GD speakers. It is highly unlikely that such a difference in F0, which was consistent for both men and women, could reflect physical differences between the speakers of the two dialects. It is more conceivable that this difference is related to cultural and interpersonal communication pattern differences. Yet, before any firm conclusion is drawn on this issue, this finding should be replicated and verified over a larger sample.

B. Short vowels

In both dialects, short vowels indeed have a shorter duration than the long vowels, with some minor variability for different vowel pairs, but no difference between dialects. Additionally, the short vowels were found to be more central in the F1-F2 plane than the long ones. This has been found also in other Arabic dialects, as well as other languages where short and long vowels are phonemically distinct (Disner, 1983; Pätzold and Simpson, 1997; Newman and Verhoeven, 2002; Al-Tamimi and Barkat-Defradas, 2003). However, in contrast to the findings on the long vowels, results for the short vowels revealed marked differences between the two studied dialects. We conclude that the shape of the vowel space for short vowels is specific to dialect. The properties of the short vowels' spaces are as follows.

1. Height

In MD, vowel centralization occurs differently in front versus back vowels. The front-high short vowel /i/ has the same height as its long version (/i:/). In contrast, the front-mid short vowel /e/ is raised, relatively to its long version (/e:/), which results in a merging of both short front vowels (/i/ and /e/).

While centralization in the F1-F2 plane is clearly evident in MD, its pattern is skewed, such that it affects the height of /e, a, u/ but not that of /i/ and /o/. In contrast to MD, centralization of vowel height in GD is more symmetric. Specifically, the mid vowels /e/ and /o/ have the same heights as their long counterparts. At the same time, the two high vowels /i/ and /u/ are lowered while the low vowel /a/ is raised in comparison with the long equivalents. Although some differences in this pattern were observed between men and women, they were minor, inconsistent, and non-significant.

Men's and women's short vowel spaces have similar shapes within each dialect (as illustrated in Fig. 2). This suggests that while gender differences affect absolute vowel formant values, the overall vowel space pattern is specific to dialect.

2. Height categories of short vowels

As for the long vowels, three distinct height categories of back vowels emerged in both dialects (high, mid, low). In contrast to the long vowels, however, these three categories are consistent for back vowels, but not for front vowels. In GD, three distinct height categories were observed for the front short vowels, in both genders. However, in MD, male speakers exhibited overlapping vowel heights of the /i/ and /e/ vowels, suggesting the existence of only two height categories for front vowels. This was not found in women of that dialect. Hence, it is concluded that the distinction between /i/ and /e/ may not be phonemically essential.

3. Front/back tongue position

Overall, tongue position is more centralized in short vowels than in long ones. The high vowels (/i/ and /u/) have a more central tongue position than their long counterparts, the intermediate height vowels (/e/ and /o/) are affected in different degrees, and tongue position of the central vowel /a/ is not affected at all by vowel length. In contrast to the inter-dialect differences observed for vowel height, our findings demonstrate that tongue position is not markedly affected by dialect, or gender.

4. Duration

As expected, duration differences between short and long vowels were found to be systematic and consistent, across both genders and dialects, leading to the conclusion that long vowels are approximately twice as long as short vowels. In addition, differences in duration among the short vowels are similar to the differences among long vowels. For example, the mean difference in duration between the low vowel /a:/ and the two high vowels /i:, u:/ was approximately 17 ms, respectively, which was very similar to the corresponding differences in mean duration for short vowels, 14 ms. It therefore appears that the duration difference between high and low vowels is determined by the articulatory activity, but is not a distinguishing feature between them. These findings are in line with previous studies (e.g., Newman and Verhoeven, 2002; Abudalbuh, 2011).

C. Comparing the MD and GD dialects

Various contrasts and similarities between GD and MD were noted throughout the comparisons above. These are summarized as follows:

(1) Formant spaces of *long* vowels: there are practically no differences between dialects with respect to long vowels. Both dialects have five distinct long vowels, with three height categories and five tongue placement categories.
(2) Formant spaces of *short* vowels: centralization in the F1-F2 plane is apparent in both dialects. However, this is manifested differently in each dialect, and it is the most prominent differentiating factor between the vowel systems of these dialects.
(3) Duration: differences between short and long vowels are large and similar across dialects. Furthermore, as duration is an important and fundamental phonetic feature in CAI (and in other Eastern CA dialects and MSA), it appears to be employed similarly in both dialects.
(4) F0: overall fundamental frequency differences found between the two dialects were surprising and unexpected. Speakers of MD (both men and women) exhibited higher average F0 values than speakers of GD.

V. CONCLUSION

This study is the first comparative description of the acoustic properties of vowels produced by native speakers of Arabic in the Muthallath and Galilee regions in Israel. It provides normative acoustic data for the vowel systems of the MD and GD dialects, demonstrating that both dialects have similar, but not identical vowel systems. First, our findings confirm that there is a phonemic difference in duration between long and short vowels in both dialects of CAI. Second, both vowel systems have the same long-vowel spaces, which might indicate that this is a property common to more CA dialects. It may also indicate that long vowels are a more stable component of the vowel system, and therefore less susceptible to change. Finally, we have shown that duration is not the only factor in differentiating short and long vowels, as the vowel space of short vowels is more centralized, leading in some cases to merging of short vowel categories. This centralization is not necessarily symmetric, and the differences in centralization patterns are the main distinguishing factor between the two dialects.

These findings appear to be only the tip of the iceberg regarding the acoustic-phonetic aspects of CAI. Additional features that should be addressed in future studies are the effect of adjacent voiced/voiceless consonants on vowel durations, as well as emphatic (pharyngealized) vs non-emphatic (consonantal) phonetic environments on vowel durations and formants. Other differences may be found between our results and those of dialects in various parts of the country and other communal dialects, such as various

TABLE V. Lists of MD and GD test words (Word stress is placed on the first vowel in all words).

List A		List B		List C	
Arabic phonetic	gloss	Arabic phonetic	gloss	Arabic word	gloss
bi:r	water well	fi:l	elephant	MD ri:ħ GD: ki:s	wind bag
MD: fe:n GD: we:n	fan (hair) where	se:f	sword	ze:t	oil
na:r	fire	da:r	house, home	ba:b	door
mo:z	bananas	MD: bo:t GD: lo:z	shoe almonds	mo:t	death
tu:t	strawberries	fu:l	broad beans	MD: mu:s GD: ħu:t	knife fish
MD: ridʒel GD: ʔidʒer	leg	miter	meter	bizer	seeds
bes(s)	cat	MD: med(d) GD: ʃed(d)	stretched	MD: dʒeb GD: ʕed(d)	jeep count
batˤ(tˤ)	ducks	raf(f)	shelf	sadd	blocked
dob(b)	bear	dob(b)	bear	rod(d)	answer
sufun	ships	mudon	towns	MD: furun GD: furon	oven

Bedouin dialects. In particular, the proximity of /i-e/ and /o-u/ warrant additional study in other Arabic dialects.

ACKNOWLEDGMENTS

We cordially thank Rizan Rabi, Sadja Hagala-'Asi, Saleem Haj, and Najla Kassis for their assistance in collecting the data and carrying out part of the analysis.

APPENDIX

Table V is organized by vowel, with words containing long vowels preceding words with short ones. In some cases, words for the two dialects differ due to inter-dialect lexical or phonetic differences. In such cases, the respective dialect word is marked as GD or MD. The letters in brackets mark consonants which are geminated, though not always audibly so. The target vowel in all the two-syllable words was the first vowel. In all the words used here, this was the stressed vowel.

[1]Although our study is not concerned with MSA, we mention this because speakers use mainly CA phonetic features in spoken MSA (Newman and Verhoeven, 2002; Embarki *et al.*, 2011). While CA is these speakers' native language, used mainly for informal communication, MSA is the formal schooled register and, in fact, speakers' L2 (Mejdell, 2006).

[2]Today they are "ex-nomadic" since their speakers have also settled down in villages, as in many other Middle Eastern countries (Rosenhouse, 1984).

[3]Language-dependent morphophonological limitations affect word lists also in other publications; e.g., Tsukada (2009) uses CVCVCV words for Japanese but CVC words for the Arabic and Thai parts of her study.

[4]Arabic texts are usually written without diacritical vowel marks. Still, the vowels were marked in several words in the MG text in order to ascertain correct reading.

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