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Acoustic Analysis of Arabic Short vs. Long Vowels Following Emphatic and Non-Emphatic Consonants by Speakers of Najdi Dialect

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Abstract
This study examines the acoustic characteristics of Modern Standard Arabic vowels produced by 11 Najdi Arabic speakers. In particular, the study explores the difference between short vowels (/i, a, u/) and their long counterparts (/i:, a:, u:/) in terms of duration and quality in two contexts. In the first context, short and long vowels were preceded by plain consonants /t/ and /s/. In the second context, short and long vowels were preceded by emphatic consonants /tˤ/ and /sˤ/. Each vowel was used in a plain frame and in its emphatic counterpart that differed in only the presence of the emphatic feature of the initial consonant (e.g., /t_b/ vs. /tˤ_b/). Each target word or nonword was embedded in a carrier sentence. Vowel duration and F1 and F2 of short and long vowels were measured. The results showed that long vowels (212 ms) were 2.4 times longer than short vowels (88 ms) in the plain context. In the emphatic context, long vowels (219 ms) were also 2.4 times longer than short vowels (92 ms). There was no interaction between vowel length and vowel context, suggesting that the difference in duration of short and long vowels was the same in the two contexts. In terms of quality in plain and emphatic contexts, the vowel /i/ had a higher F1 and a lower F2 than /i:/. The vowel /u/ had a higher F1 and F2 than /u:/. The vowel /a/ had a lower F1 and a higher F2 than /a:/.

Keywords: Najdi Arabic, short and long vowels, emphasis, vowel duration, vowel quality.

1. Introduction

The vowel system of Modern Standard Arabic (MSA) consists of three vowels (/i/, /a/, /u/) and their long versions (/i:/, /a:/, /u:/) (e.g., Al-Ani, 1970; Alghamdi, 1998; Alotaibi & Husain, 2010). Vowel length in MSA is phonemic (e.g., Alghamdi, 1998; Mitleb, 1984). Example (1) shows a minimal pair of MSA words that differ in the length of the vowel /u/. Emphasis in MSA is also phonemic (e.g., Abudalbuh, 2010; Al-Masri & Jongman, 2004). Example (2) shows a minimal pair of MSA words that differ in the presence of the emphatic feature of the initial consonant. *Emphasis* refers to consonants that are produced with a primary constriction in the dental or alveolar region and a secondary constriction in the back of the vocal tract (e.g., Aldamen & Al-Deaibes, 2023; Davis, 1995; Kahn, 1975; McCarthy, 1994; Zemánek, 2006).

(1) /sud/ /su:d/
"you block" "black (pl.)"

(2) /sa:d/ /sˤa:d/
"it prevailed" "he hunted"

Previous research investigated the acoustic characteristics of MSA vowels in various dialects (e.g., Abou Haidar, 1994; Ahmed, 2008; Almbark & Hellmuth, 2015; Alotaibi & Hussain, 2009; Belkaid, 1984; Ghazeli, 1979; Kalaldeh, 2018; Nasr, 1960; Newman & Verhoeven, 2002). In an early acoustic study, Al-Ani (1970) examined MSA vowels produced by eight Iraqis and two Jordanians in terms of duration and quality. In terms of duration, Al-Ani found the durations of the long vowels were almost twice those of their short counterparts. In terms of quality, there was no difference in F1 and F2 between the vowels (/i/, /u/) and their long counterparts (/i:/, /u:/). However, the short vowel /a/ had a lower F1 and a higher F2 than its long counterpart /a:/. These results suggest that short and long vowels produced by the Iraqi and Jordanian speakers differ substantially in duration. In terms of quality, the difference was only between the vowel /a/ and its long counterpart /a:/. It should be noted that this study examined MSA vowels only in a plain context in which vowels were preceded by non-emphatic consonants.

Another study that examined the acoustic characteristics of MSA vowels is Alghamdi (1998). Like Al-Ani (1970), this study investigated MSA vowels only in a plain context. The study tested whether short and long vowels in MSA were the same phonetically when produced by speakers of different dialects. The study tested Saudi, Sudanese, and Egyptian speakers. Similar to the vowel duration results of Al-Ani (1970), the results showed that in each dialect the durations of long vowels were two times longer than their short counterparts. In terms of quality, the results showed that in each dialect the vowel /i/ had a higher F1 and a lower F2 than its long counterpart and the vowel /u/ had a higher F1 and a higher F2 than its long counterpart. The vowel /a/ in the Saudi dialect had a lower F1 and a comparable F2 compared to its long counterpart. In the Egyptian dialect, the vowel /a/ had a comparable F1 and a lower F2 compared to its long counterpart. In the Sudanese dialect, it had a lower F1 and a higher F2 than its long counterpart. These results suggest that short and long vowels produced by the Saudi, Sudanese, and Egyptian speakers differ in terms of duration and quality.

Saadah (2011) examined the acoustic characteristics of MSA vowels produced by Palestinian speakers. Like Al-Ani (1970) and Alghamdi (1998), Saadah's (2011) study explored the difference between short and long vowels only in a plain context in which the vowels were preceded by non-emphatic consonants. Similar to the results of Al-Ani (1970) and Alghamdi (1998), Saadah's (2011) results showed that the durations of long vowels were two times longer than their short counterparts. In terms of vowel quality, the results were similar to the vowel quality results of Saudi speakers in Alghamdi (1998). Specifically, the vowel /i/ had a higher F1 and a lower F2 than its long counterpart and the vowel /u/ had a higher F1 and F2 than its long counterpart. The vowel /a/ had a lower F1 and a comparable F2 as compared to its long counterpart. These results suggest that short and long vowels produced by Palestinian speakers differ in terms of duration and quality.

Although Saadah (2011) did not compare short vowels to their long counterparts when preceded by emphatic consonants (e.g., /sˤib/ vs. /sˤi:b/), she compared each vowel when preceded by a plain vs. emphatic consonant (e.g., /sib/ vs. /sˤib/) in terms of quality. In general, vowels preceded by emphatic consonants had a comparable F1 and a lower F2 compared to their counterparts preceded by plain consonants.

Like Saadah (2011), Jongman et al. (2011) did not compare short vowels to their long counterparts when preceded by emphatic consonants. However, Jongman et al. (2011) compared each vowel when preceded by a plain vs. emphatic consonant in terms of quality. Jongman et al., who tested Jordanian speakers, found that vowels preceded by emphatic consonants had a higher F1 and a lower F2 than their vowel counterparts preceded by plain consonants.

Also, similar to Saadah (2011) and Jongman et al. (2011), Abudalbuh (2010) did not examine duration and quality differences between short vowels and their long counterparts when preceded by emphatic consonants. Instead, Abudalbuh (2010) compared each of the long vowels (/i:, a:, u:/) when preceded by a plain vs. emphatic consonant in terms of duration and quality. Abudalbuh, who examined Jordanian speakers, showed that emphatic long vowels (224 ms) had a longer duration than their plain counterparts (216 ms). In terms of quality, emphatic vowels had a raised F1 and a lowered F2 compared to their plain counterparts**.**

2. The Present Study

Al-Ani (1970), Alghamdi (1998), and Saadah (2011) examined duration and quality differences between short and long vowels in various dialects of MSA. However, these studies examined the differences between short and long vowels in a plain context in which the vowels were preceded by non-emphatic consonants (e.g., /t/ and /s/) and did not explore the differences between short and long vowels in an emphatic context in which the vowels were preceded by emphatic consonants (e.g., /tˤ/ and /sˤ/). Although some studies have investigated the effects of emphasis on vowels in various dialects of MSA (e.g., Abudalbuh, 2010; Jongman et al., 2011; Saadah, 2011), these studies did not compare each short vowel to its long counterpart when preceded by emphatic consonants (e.g., /sˤib/ vs. /sˤi:b/). Instead, these studies compared each vowel when preceded by a plain vs. emphatic consonant (e.g., /sib/ vs. /sˤib/) in terms of duration (e.g., Jongman et al., 2011; Saadah, 2011) and quality (e.g., Abudalbuh, 2010).

The goal of the present study is to investigate the acoustic characteristics of MSA vowels produced by Najdi Arabic speakers. Specifically, this study examines the differences between short vowels (/i, a, u/) and their long counterparts (/i:, a:, u:/) in terms of duration and quality in two contexts. In the first context, the short vowels and their long counterparts are preceded by non-emphatic consonants. In the second context, the short vowels and their long counterparts are preceded by emphatic consonants.

2.1 Method

2.1.1 Stimulus Materials

The target vowels consisted of the vowels (/i/, /a/, /u/) and their long counterparts (/i:/, /a:/, /u:/) in MSA. Each vowel was used in a plain frame (e.g., /t_b/) and its emphatic counterpart (e.g., /tˤ_b/), which differed only in the emphatic feature of the initial consonant. The four plain frames and their emphatic counterparts that were used were: (/t_b/ vs. /tˤ_b/), (/t_d/ vs. /tˤ_d/), (/s_b/ vs. /sˤ_b/) and (/s_d/ vs. /sˤ_d/). To control for the context of the examined vowels, the vowels were preceded by either a voiceless alveolar stop /t/ or a voiceless alveolar fricative /s/ and followed by either a voiced bilabial stop /b/ or a voiced alveolar stop /d/. Using a plain frame and its emphatic counterpart allowed to compare each vowel with its long counterpart in terms of duration and quality in both a plain context and an emphatic context. It would also allow to compare each vowel in a plain vs. emphatic context in terms of both duration and quality.

The stimuli consisted of monosyllabic words and nonwords as shown in the Appendix. Each target word or nonword was embedded in the carrier phrase [ʔna: agu:l _ bisuhu:lah], which

means in English “I say _ easily.” The stimuli were printed in MSA script supplemented with diacritic markings. Speakers were asked to read the randomized stimuli at a normal speaking rate. Each stimulus was repeated three times by subjects. The total number of stimuli per speaker was 144, including 72 plain stimuli and 72 emphatic stimuli (8 syllable frames × 6 vowels × 3 repetitions).

2.1.2 Participants

Eleven adult male speakers voluntarily participated in the study and were recorded. All participants in the study were native speakers of Najdi Arabic dialect with no known history of either speech or hearing impairment. All participants were students at the University of Kansas, United States, at the time of the study.

2.1.3 Recordings

Speakers were recorded in an anechoic chamber, using a cardioid microphone (Electro-Voice, model 767) and a solid-state digital recorder (Marantz PMD671) at a sampling rate of 22050 Hz.

2.1.4 Measurements

All measurements were taken using Praat speech-analysis software (Boersma & Weenink, 2007). Vowel onset was taken as the clear emergence of F1 on the spectrogram. Vowel offset was taken as the point at which F2 substantially weakened on the spectrogram. F1 and F2 measures were taken at the middle of the vowel.

3. Results

3.1 Duration

A three-way repeated measures analysis of variance (ANOVA), with vowel length, vowel context, and vowel quality as independent variables, was conducted for vowel duration. As expected, vowel duration exhibited a main effect for vowel length, with long vowels (215 ms) having significantly longer duration than short vowels (90 ms) [$F(1,10) = 62.922$, $p = .000$]. There was also a main effect of vowel context, with a significantly longer duration for vowels in the emphatic context (156 ms) than for vowels in the plain context (150 ms) [$F(1,10) = 9.876$, $p = .010$]. Moreover, there was a main effect of vowel quality [$F(2,10) = 5.856$, $p = .010$]. Bonferroni post hoc analysis showed that duration for /a/ (158 ms) was significantly longer than duration for /i/ (148 ms) but not for /u/ (153 ms). For vowel duration, there was a significant interaction between vowel context and vowel quality [$F(1,10) = 4.550$, $p = .029$], indicating that the effect of emphasis on vowel duration was more pronounced for /i/ and /u/ than for /a/. However, there was no significant interaction between vowel length and vowel context [$F(1,10) = 1.196$, $p = .300$], indicating that the difference between the duration of short and long vowels is the same in the plain and emphatic contexts, as shown in Figure 1.

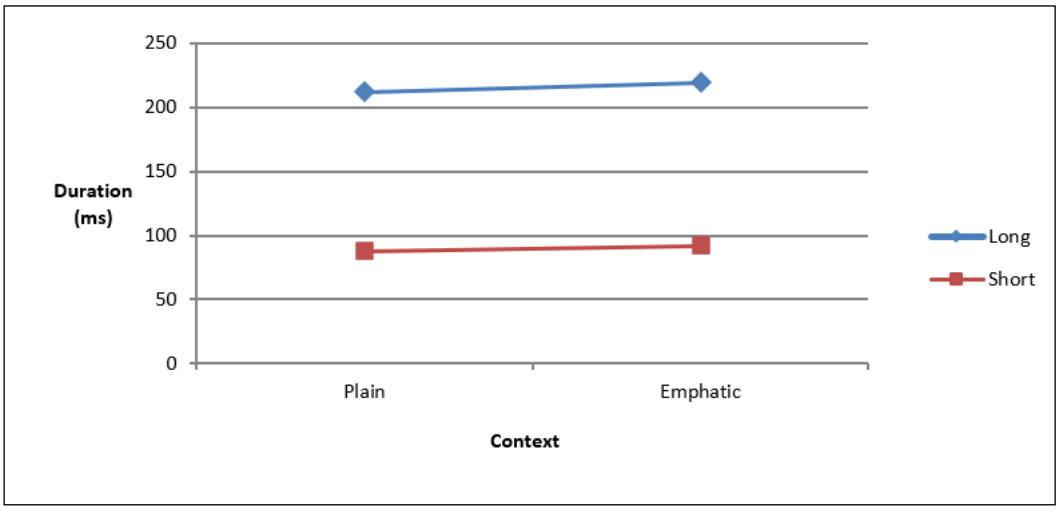

Figure 1. Short and Long Vowels in Plain vs. Emphatic Context

3.1.1 Plain Context

A two-way repeated measures ANOVA, with vowel length and vowel quality as independent variables, was conducted for vowel duration. Vowel duration had a main effect for vowel length, with long vowels (212 ms) having significantly longer duration than short vowels (88 ms) [$F(1,10) = 65.380$, $p = .000$]. There was also a main effect of vowel quality [$F(2,10) = 10.757$, $p = .001$]. Bonferroni post hoc analysis showed that duration for /a/ (158 ms) was significantly longer than duration for /i/ (142 ms) but not for /u/ (150 ms). For vowel duration, there was no significant interaction between vowel length and vowel quality [$F(1,10) = .275$, $p = .661$]. Overall, long vowels (212 ms) were about 2.4 times longer than short vowels (88 ms) when preceded by plain consonants /t/ and /s/ as shown in Table 1.

Table 1. Duration of Long vs. Short Vowels Preceded by Plain Consonants

Long vs. short Vowels	Duration (ms)	Long to short vowel duration ratio
i: vs. i	(203) vs. (81)	2.5 : 1
a: vs. a	(220) vs. (95)	2.3 : 1
u: vs. u	(212) vs. (88)	2.4 : 1

3.1.2 Emphatic Context

A two-way repeated measures ANOVA, with vowel length and vowel quality as independent variables, was conducted for vowel duration. As expected, vowel duration exhibited a main effect for vowel length, with long vowels (219 ms) having significantly longer duration than short vowels (92 ms) [$F(1,10) = 59.661$, $p = .000$]. There was no main effect of vowel quality [$F(2,10) = .669$, $p = .523$]. There was also no significant interaction between vowel length and vowel quality [$F(2,10) = .327$, $p = .640$]. Overall, long vowels (219 ms) were about 2.4 times longer than short vowels (92 ms) when preceded by emphatic consonants /tˤ/ and /sˤ/ as shown in Table 2.

Table 2. Duration of Long vs. Short Vowels Preceded by Emphatic Consonants

Long vs. short Vowels	Duration (ms)	Long to short vowel duration ratio
i: vs. i	(216) vs. (90)	2.4 : 1
a: vs. a	(220) vs. (94)	2.3 : 1
u: vs. u	(221) vs. (91)	2.4 : 1

3.1.3 Plain vs. Emphatic Context

Long vowels (219 ms) in emphatic context were significantly longer than long vowels (212 ms) in plain context [$t(10) = -2.329$, $p = .042$]. Short vowels (92 ms) in emphatic context were also significantly longer than short vowels (88 ms) in plain context [$t(10) = 2.878$, $p = .016$]. Emphatic /i:/ (216 ms) was significantly longer than plain /i:/ (203 ms) [$t(10) = -3.101$, $p = .011$]. Emphatic /i/ (90 ms) was significantly longer than plain /i/ (81 ms) [$t(10) = -4.655$, $p = .001$]. Emphatic /a:/ (220 ms) had the same duration as plain /a:/ (220 ms). Emphatic /a/ (94 ms) was slightly shorter than plain /a/ (95 ms). Emphatic /u:/ (221 ms) was longer than plain /u:/ (212 ms), with a difference close to significance [$t(10) = 2.204$, $p = .052$]. Emphatic /u/ (91 ms) was significantly longer than plain /u/ (88 ms) [$t(1,10) = -2.991$, $p = .014$].

3.2 Vowel Quality

A three-way repeated measures ANOVA, with vowel length, vowel context, and vowel quality as independent variables, was conducted for F1 and F2. Both F1 and F2 exhibited a main effect for vowel length. Short vowels had a significantly higher F1 (536 Hz) [$F(1,10) = 16.830$, $p = .002$] and a significantly lower F2 (1454 Hz) [$F(1,10) = 7.508$, $p = .021$] than long vowels F1 (491 Hz) and F2 (1495 Hz). Both F1 and F2 also exhibited a main effect for vowel context**.** F1 (526 Hz) was significantly higher following an emphatic consonant than a plain consonant F1 (501 Hz) [$F(1,10) = 150.417$, $p = .000$]. F2 (1378 Hz) was significantly lower following an emphatic consonant than a plain consonant F2 (1571 Hz) [$F(1,10) = 213.793$, $p = .000$]. Significant interactions between vowel length and vowel context for F1 and F2, [$F(1,10) = 13.586$, $p = .004$] and [$F(1,10) = 40.567$, $p = .000$], indicated that the effect of emphasis was more pronounced in short vowels than in long vowels. This is illustrated in Figures 2 and 3.

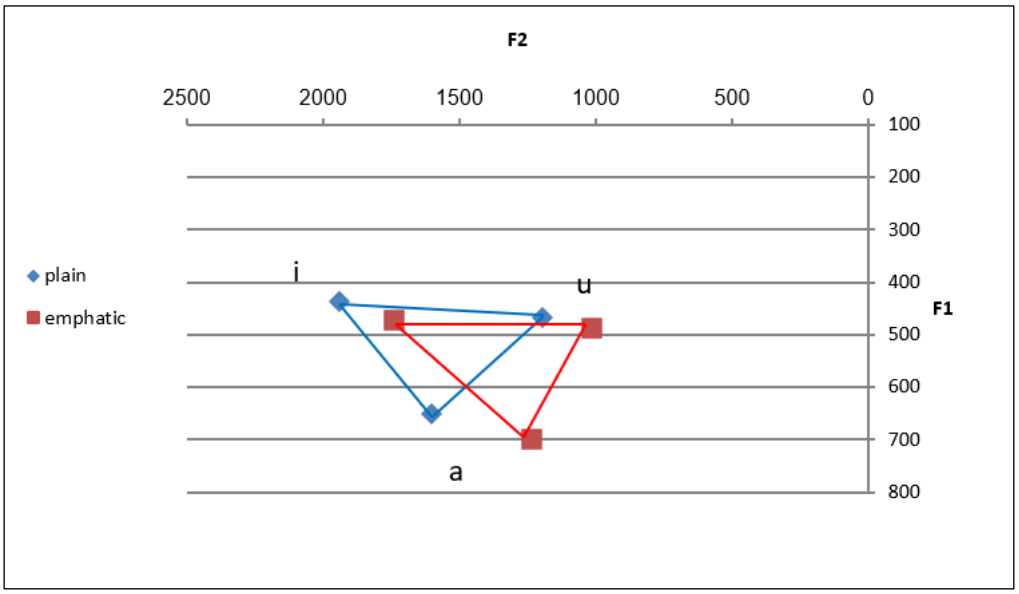

Figure 2. Short Vowels in Plain vs. Emphatic Context

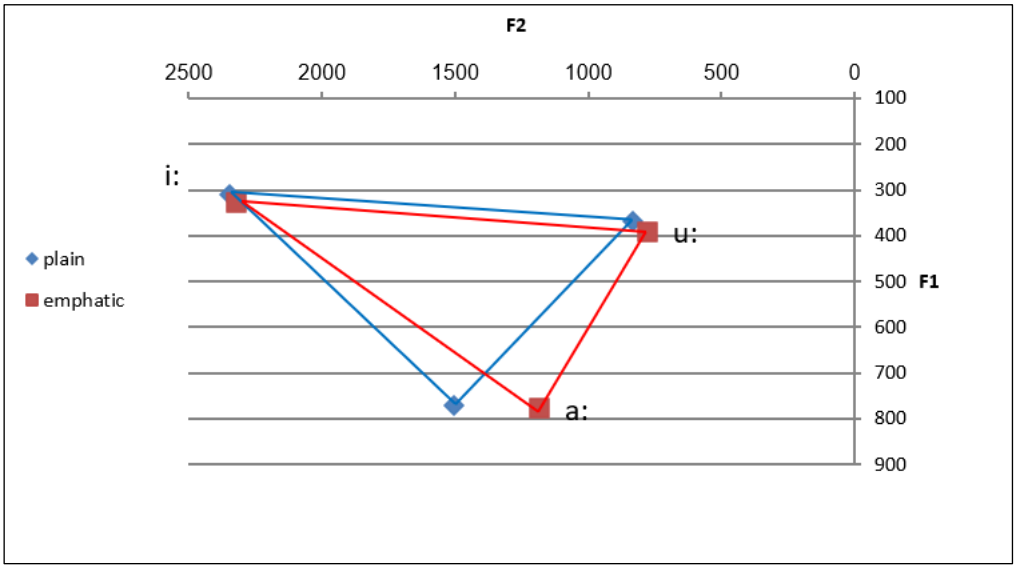

Figure 3. Long Vowels in Plain vs. Emphatic Context

For F1, there was a main effect of vowel quality [$F(2,10) = 150.417$, $p = .000$]. Bonferroni post hoc analysis showed that F1 was significantly higher for /a/ (725 Hz) than for /u/ (429 Hz), which was in turn significantly higher than /i/ (387 Hz). For F2, there was a main effect of vowel quality [$F(2,10) = 605.470$, $p = .000$]. Bonferroni post hoc analysis showed that F2 was significantly higher for /i/ (2087 Hz) than for /a/ (1382 Hz), which was in turn significantly higher than /u/ (955 Hz). For F2, a significant interaction between vowel quality and vowel context indicated that emphasis had a stronger effect for the vowels /a/ and /u/ than for /i/ [$F(1,10) = 84.988$, $p = .000$].

3.2.1 Plain Context

A two-way repeated measures ANOVA, with vowel length and vowel quality as independent variables, was conducted for F1 and F2. F1 exhibited a main effect for vowel length [$F(1,10) = 8.558$, $p = .015$], with short vowels having a significantly higher F1 (519 Hz) than long vowels

F1 (483 Hz). F2 did not show a main effect for vowel length [$F(1,10) = 1.048$, $p = .330$]. F1 also exhibited a main effect for vowel quality [$F(2,10) = 402.574$, $p = .000$]. Bonferroni post hoc analysis showed that F1 was significantly higher for /a/ (711 Hz) than for /u/ (417 Hz), which was in turn significantly higher than /i/ (374 Hz). F2 also exhibited a main effect for vowel quality [$F(2,10) = 512.402$, $p = .000$]. Bonferroni post hoc analysis showed that F2 was significantly higher for /i/ (2143 Hz) than for /a/ (1554 Hz), which was in turn significantly higher than /u/ (1014 Hz). There was a significant interaction between vowel length and vowel quality for F1 [$F(1,10) = 108.819$, $p = .000$], indicating that the effect of vowel length on F1 was more pronounced in /i/ and /u/ than in /a/. There was also a significant interaction between vowel length and vowel quality for F2, [$F(1,10) = 216.073$, $p = .000$], indicating that the effect of vowel length on F2 was also more pronounced in /i/ and /u/ than in /a/.

Figure 4 shows the acoustic space of short vs. long Arabic vowels when preceded by plain consonants /t/ and /s/. In terms of vowel quality, the results showed that F1 for short vowel /i/ (438 Hz) was significantly higher than F1 for long /i:/ (309 Hz) [$t(10) = 7.161$, $p = .000$], whereas F2 for short vowel /i/ (1939 Hz) was significantly lower than F2 for long /i:/ (2347 Hz) [$t(10) = -14.143$, $p = .000$]. F1 for short vowel /u/ (467 Hz) was significantly higher than F1 for long /u:/ (369 Hz) [$t(10) = 6.314$, $p = .000$], and F2 for short vowel /u/ (1194 Hz) was significantly higher than F2 for long /u:/ (833 Hz) [$t(10) = 13.079$, $p = .000$].

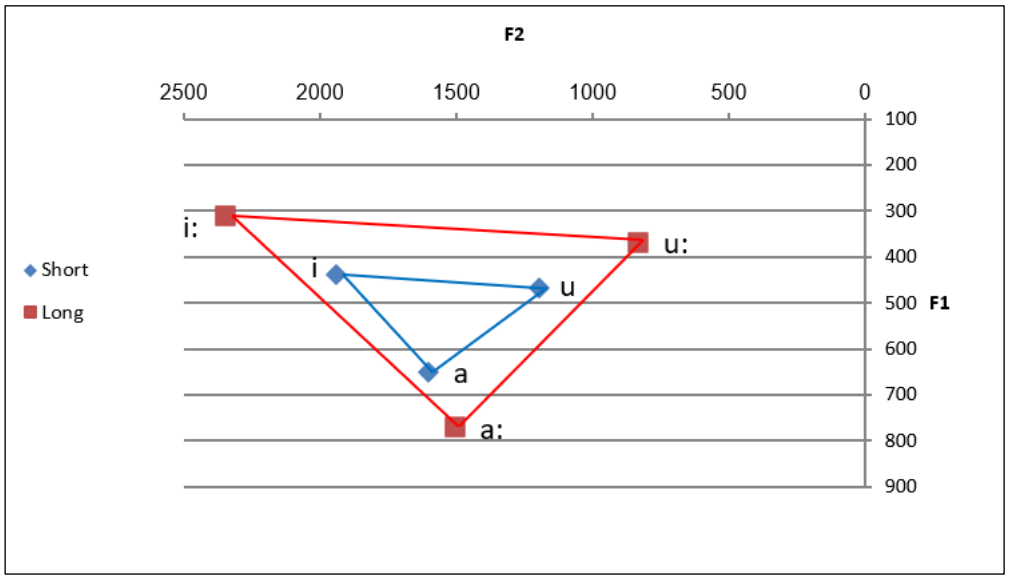

Figure 4. Short vs. Long Vowels in Plain Context

F1 for short vowel /a/ (651 Hz) was significantly lower than F1 for long /a:/ (771 Hz) [$t(10) = -7.981$, $p = .000$], whereas F2 for short vowel /a/ (1603 Hz) was significantly higher than F2 for long /a:/ (1506 Hz) [$t(10) = 4.030$, $p = .000$]. As shown in Figure 4, long vowels were more peripheral than their short counterparts in F1 and F2 acoustic space. These results in general indicate that short vs. long Arabic vowels were different in terms of quality when preceded by plain consonants.

3.2.2 Emphatic Context

A two-way repeated measures ANOVA, with vowel length and vowel quality as independent variables, was conducted for F1 and F2. F1 exhibited a main effect for vowel length [$F(1,10) = 29.197$, $p = .000$], with short vowels having a significantly higher F1 (553 Hz) than long vowels F1 (499 Hz). F2 also showed a main effect for vowel length [$F(1,10) = 27.028$, $p = .000$],

with short vowels having a significantly lower F2 (1329 Hz) than long vowels F2 (1428 Hz). F1 also exhibited a main effect for vowel quality [$F(2,10) = 368.895$, $p = .000$]. Bonferroni post hoc analysis showed that F1 was significantly higher for /a/ (738 Hz) than for /u/ (439 Hz), which was in turn significantly higher than /i/ (401 Hz). F2 also exhibited a main effect for vowel quality [$F(2,10) = 613.437$, $p = .000$]. Bonferroni post hoc analysis showed that F2 was significantly higher for /i/ (2030 Hz) than for /a/ (1210 Hz), which was in turn significantly higher than /u/ (896 Hz). There was a significant interaction between vowel length and vowel quality for F1 [$F(1,10) = 86.054$, $p = .000$], indicating that the effect of vowel length on F1 was more pronounced in /i/ and /u/ than in /a/. There was also a significant interaction between vowel length and vowel quality for F2, [$F(1,10) = 232.687$, $p = .000$], indicating that the effect of vowel length on F2 was also more pronounced in /i/ and /u/ than in /a/.

Figure 5 shows the acoustic space of short vs. long Arabic vowels when preceded by emphatic consonants /tˤ/ and /sˤ/. In terms of vowel quality, the results showed that F1 for short vowel /i/ (473 Hz) was significantly higher than F1 for long /i:/ (328 Hz) [$t(10) = 8.464$, $p = .000$], whereas F2 for short vowel /i/ (1738 Hz) was significantly lower than F2 for long /i:/ (2321 Hz) [$t(10) = -14.543$, $p = .000$]. F1 for short vowel /u/ (487 Hz) was significantly higher than F1 for long /u:/ (391 Hz) [$t(10) = 5.973$, $p = .000$], and F2 for short vowel /u/ (1013 Hz) was significantly higher than F2 for long /u:/ (778 Hz) [$t(10) = 9.118$, $p = .000$].

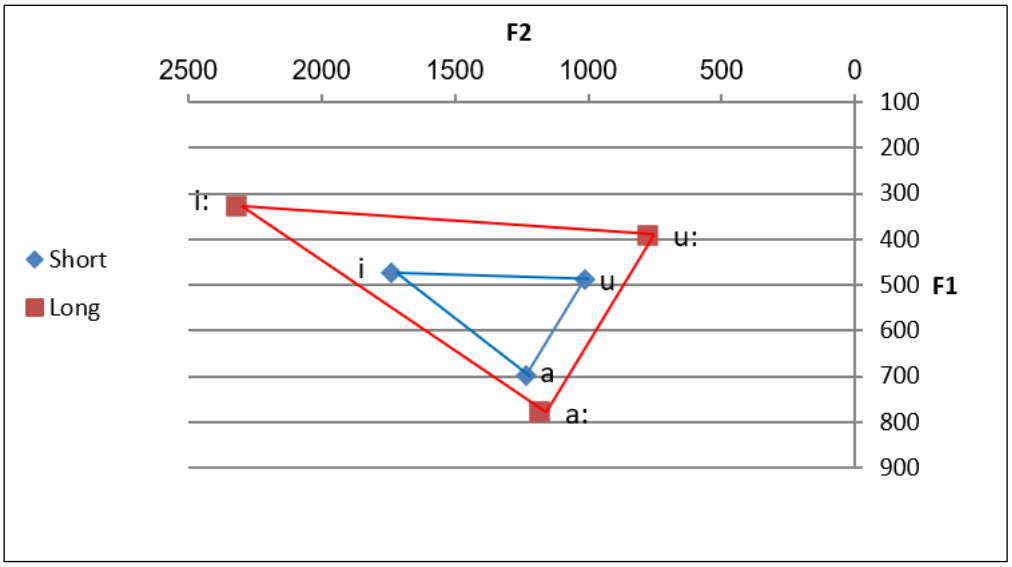

Figure 5. Short vs. Long Vowels in Emphatic Context

F1 for short vowel /a/ (699 Hz) was significantly lower than F1 for long /a:/ (778 Hz) [$t(10) = -9.484$, $p = .000$], whereas F2 for short vowel /a/ (1235 Hz) was significantly higher than F2 for long /a:/ (1183 Hz) [$t(10) = 2.608$, $p = .026$]. As shown in Figure 5, long vowels were again more peripheral than their short counterparts in F1 and F2 acoustic space. These results in general show that short vs. long Arabic vowels were different in terms of quality when preceded by emphatic consonants.

3.2.3 Plain vs. Emphatic Context

Figure 6 shows the acoustic space of short and long Arabic vowels when preceded by plain consonants /t/ and /s/ vs. emphatic consonants /tˤ/ and /sˤ/. The emphatic short vowel /i/ had a significantly higher F1 (473 Hz) [$t(10) = 6.720$, $p = .000$] and a significantly lower F2 (1738 Hz) [$t(10) = -9.256$, $p = .000$] compared to F1 (438 Hz) and F2 (1939 Hz) of plain short vowel

/i/. The emphatic long vowel /i:/ had a significantly higher F1 (328 Hz) [$t(10) = 5.453$, $p = .000$] and a lower F2 (2321 Hz) [$t(10) = -1.975$, $p = .077$] compared to F1 (309 Hz) and F2 (2347 Hz) of plain long vowel /i:/. The emphatic short vowel /u/ had a significantly higher F1 (487 Hz) [$t(10) = 4.676$, $p = .001$] and a significantly lower F2 (1013 Hz) [$t(10) = -8.913$, $p = .000$] compared to F1 (467 Hz) and F2 (1194 Hz) of plain short vowel /u/. The emphatic long vowel /u:/ had a significantly higher F1 (391 Hz) [$t(10) = 3.101$, p =.011] and a significantly lower F2 (778 Hz) [$t(10) = -4.988$, $p = .001$] compared to F1 (369 Hz) and F2 (833 Hz) of plain long vowel /u:/.

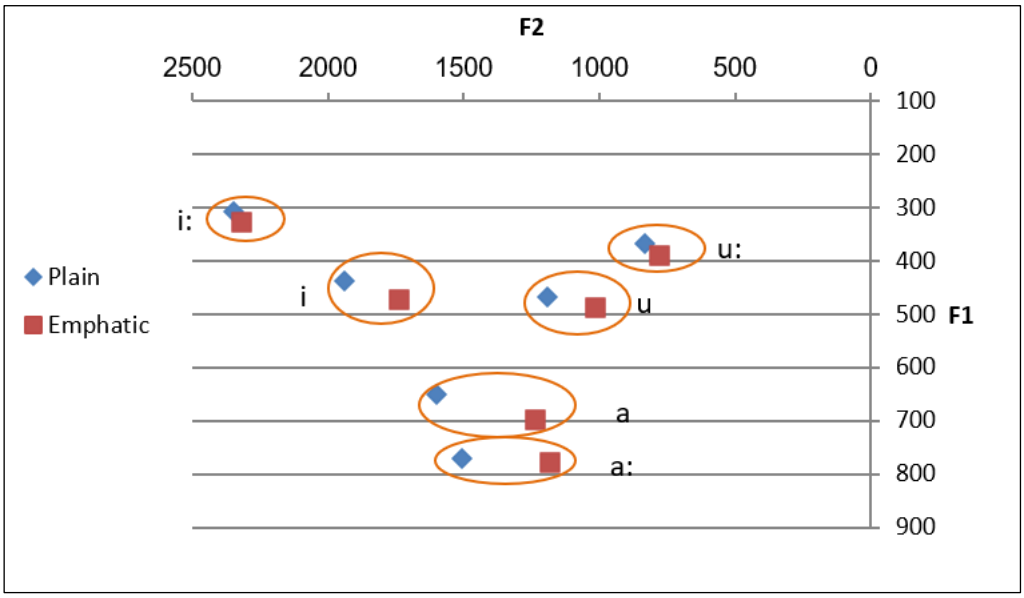

Figure 6. Short and Long Vowels in Plain vs. Emphatic Context

The emphatic short vowel /a/ had a significantly higher F1 (699 Hz) [$t(10) = 4.710$, $p = .001$] and a significantly lower F2 (1235 Hz) [$t(10) = -12.904$, $p = .000$] compared to F1 (651 Hz) and F2 (1603 Hz) of plain short vowel /a/. The emphatic long vowel /a:/ had a higher F1 (778 Hz) [$t(10) = .705$, $p = .497$] and a significantly lower F2 (1183 Hz) [$t(10) = -13.637$, $p = .000$] compared to F1 (771 Hz) and F2 (1506) of plain long vowel /a:/. As shown in Figure 6, F1 and F2 for the long vowels /i:/ and /u:/ were less affected by emphasis than other vowels. These results indicate that emphatic short and long Arabic vowels in general tended to have a backer and higher position in F1 and F2 acoustic space compared to their plain counterparts.

The F1 difference for /i/ vs. /i:/ in plain context (129 Hz) was significantly smaller than the F1 difference in emphatic context (145 Hz) [$t(10) = -2.318$, $p = .043$]. The F2 difference for /i/ vs. /i:/ in plain context (408 Hz) was significantly smaller than the F2 difference in emphatic context (583 Hz) [$t(10) = -6.801$, $p = .000$]. The F1 difference for /u/ vs. /u:/ in plain context (98 Hz) was not significantly larger than the F1 difference in emphatic context (96 Hz) [$t(10) = .431$, $p = .675$]. The F2 difference for /u/ vs. /u:/ in plain context (361 Hz) was significantly larger than the F2 difference in emphatic context (235 Hz) [$t(10) = 6.831$, $p = .000$]. The F1 difference for /a/ vs. /a:/ in plain context (120 Hz) was significantly larger than the F1 difference in emphatic context (79 Hz) [$t(10) = 3.967$, $p = .003$]. The F2 difference for /a/ vs. /a:/ in plain context (97 Hz) was significantly larger than the F2 difference in emphatic context (52 Hz) [$t(10) = 6.831$, $p = .000$].

4. Discussion

The goal of this study was to explore the difference between short and long vowels in MSA by Najdi Arabic speakers in terms of duration and quality in both plain and emphatic contexts. In terms of duration of short vs. long vowels in the plain context, long vowels produced by Najdi Arabic speakers in this study were 2.4 times longer than short vowels. This finding is consistent with the results of earlier studies (e.g., Al-Ani, 1970; Alghamdi, 1998; Saadah, 2011) that found long vowels in various dialects of MSA were about two times longer than short vowels. As shown in Table 3, short and long vowels produced by Saudi speakers in Alghamdi (1998) were longer in duration than short and long vowels produced by Najdi Arabic speakers in this study. This could be because Alghamdi (1998) tested MSA vowels in words produced in isolation and not in a carrier phrase as was the case in this study and Saadah (2011). Of note is that the vowel /a:/ had the longest duration, whereas /i/ had the shortest duration for Saudi and Egyptian speakers in Alghamdi (1998) and Palestinian speakers in Saadah (2011), as well as Najdi Arabic speakers in this study.

Table 3. Vowel Duration (ms) of Various Dialects in Modern Standard Arabic

Study	Dialect	Vowels					
		i	i:	a	a:	u	u:
Al-Ani (1970)	Iraqi	300	600	300	600	300	600
Alghamdi (1998)	Saudi	111	248	133	311	114	137
	Sudanese	117	275	128	295	116	304
	Egyptian	98	255	122	316	110	253
Saadah (2011)	Palestinian	84	219	97	247	90	226
Present study	Najdi Arabic	81	203	95	220	88	212

In terms of duration of short vs. long vowels in the emphatic context that was not examined in previous studies (e.g., Abudalbuh, 2010; Al-Ani, 1970; Alghamdi, 1998; Jongman et al., 2011; Saadah, 2011), long vowels produced by Najdi Arabic speakers in this study were 2.4 times longer than short vowels. The vowel /u:/ had the longest duration, whereas /i/ had the shortest duration. The difference in duration between short and long vowels was the same in the plain and emphatic contexts, as reflected in the noninteraction between vowel length and vowel context. However, short and long vowels were longer in the emphatic context than in the plain context except for the low central vowels /a/ and /a:/. This finding is consistent with the results of Abudalbuh (2010), which showed long vowels produced by Jordanian Arabic speakers were in general longer in the emphatic context than in the plain context.

In terms of quality of short vs. long vowels in the plain context, short vowels produced by Najdi Arabic speakers in this study differed from their long counterparts in F1 and F2. Like the Saudi, Sudanese and Egyptian speakers in Alghamdi (1998) and the Palestinian speakers in Saadah (2011), Najdi Arabic speakers in this study produced the short vowel /i/ with a higher F1 and a lower F2 than its long counterpart and produced the short vowel /u/ with a higher F1 and F2 than its long counterpart as shown in Table 4. However, unlike Saudi speakers in Alghamdi (1998) and Palestinian speakers in Saadah (2011), who produced the short vowel /a/ with a lower F1 and a comparable F2 compared to its long counterpart, Najdi Arabic speakers in this study, like Sudanese speakers in Alghamdi (1998), produced the short vowel /a/ with a lower F1 and a higher F2 than its long counterpart. This difference in F2 could be caused by different dialects of subjects tested in these studies.

Table 4. First and Second Formant Frequencies (Hz) of Vowels in Dialects of MSA.

Study	Dialect	Vowels											
		i		i:		a		a:		u		u:	
		F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2
Al-Ani (1970)	Iraqi	290	2200	285	2200	600	1500	675	1200	290	800	285	775
Alghamdi (1998)	Saudi	402	1841	292	2286	573	1537	655	1587	451	1302	350	958
	Sudanese	331	2066	272	2255	525	1564	635	1492	354	1308	319	984
	Egyptian	357	1749	256	2175	468	1505	461	1677	370	1285	319	942
Saadah (2011)	Palestinian	467	1881	299	2437	657	1468	722	1479	467	1088	325	788
Present study	Najdi Arabic	438	1939	309	2347	651	1603	771	1506	467	1194	369	833

In terms of quality of short vs. long vowels in the emphatic context that was not examined in previous studies (e.g., Abudalbuh, 2010; Al-Ani, 1970; Alghamdi, 1998; Jongman et al., 2011; Saadah, 2011), the short vowel /i/ was produced with a higher F1 and a lower F2, the short vowel /u/ with a higher F1 and a higher F2 and the short vowel /a/ with a lower F1 and a higher F2 than their long counterparts.

In terms of vowel quality in the plain vs. emphatic context, Najdi Arabic speakers in general produced each vowel with a higher F1 and a lower F2 when preceded by an emphatic consonant compared to when preceded by a plain consonant. This finding is in line with the results of Jordanian speakers in Abudalbuh (2010) and Jongman et al. (2011) who produced vowels preceded by emphatic consonants with a higher F1 and a lower F2 than their vowel counterparts preceded by plain consonants. The emphatic long vowels /i:/ and /u:/ were less influenced by emphasis in terms of F1 and F2 compared to their short counterparts as shown in Figure 6. This is because F1 and F2 measures were taken at the middle of the vowel. The midpoint in emphatic long vowels was on average after 110 ms from the onset of the vowel while the midpoint in emphatic short vowels was after 46 ms from the onset of the vowel. Therefore, the midpoint in short vowels was closer to the effect of the initial emphatic consonants than the midpoint in their long counterparts.

5. Conclusion

This study contributes to the literature on vowels in MSA dialects. Specifically, this study sheds light into the acoustic characteristics of MSA vowels produced by Najdi Arabic speakers. Like many studies, this study phonetically examined the difference between short and long vowels following non-emphatic consonants and found that short vowels differed from their long versions in terms of duration and quality. Unlike many studies (e.g., Abudalbuh, 2010; Al-Ani, 1970; Alghamdi, 1998; Jongman et al., 2011; Saadah, 2011), however, this study not only explored the difference between short and long vowels following non-emphatic consonants but also explored the difference between short and long vowels following emphatic consonants. It

was found that short vowels differed from their long counterparts in terms of duration and quality as was the case when they were following non-emphatic consonants.

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Appendix

Table A1
Monosyllabic Words and Nonwords in the Frame /t_b/ *and the Frame* /tˤ_b/

Plain context				Emphatic context			
Word	Gloss	Word	Gloss	Word	Gloss	Word	Gloss
/tib/	you repent	/ti:b/	nonword	/tˤib/	medicine	/tˤi:b/	perfume
/tab/	nonword	/ta:b/	he repented	/tˤab/	jumped in	/tˤa:b/	he recovered
/tub/	you repent	/tu:b/	you repent	/tˤub/	jump in	/tˤu:b/	brick

Table A2
Monosyllabic Words and Nonwords in the Frame /t_d/ *vs. the Frame* /tˤ_d/

Plain context				Emphatic context			
Word	Gloss	Word	Gloss	Word	Gloss	Word	Gloss
/tid/	nonword	/ti:d/	nonword	/tˤid/	nonword	/tˤi:d/	nonword
/tad/	nonword	/ta:d/	nonword	/tˤad/	nonword	/tˤa:d/	nonword
/tud/	nonword	/tu:d/	nonword	/tˤud/	nonword	/tˤu:d/	nonword

Table A3
Monosyllabic Words and Nonwords in the Frame /s_b/ *vs. the Frame* /sˤ_b/

Plain context				Emphatic context			
Word	Gloss	Word	Gloss	Word	Gloss	Word	Gloss
/sib/	you cursed	/si:b/	you leave	/sˤib/	you score	/sˤi:b/	nonword
/sab/	he cursed	/sa:b/	he left	/sˤab/	he poured	/sˤa:b/	he scored
/sub/	nonword	/su:b/	nonword	/sˤub/	you pour	/sˤu:b/	nonword

Table A4
Monosyllabic Words and Nonwords in the Frame /s_d/ *vs. the Frame* /sˤ_d/

Plain context				Emphatic context			
Word	Gloss	Word	Gloss	Word	Gloss	Word	Gloss
/sid/	you block	/si:d/	nonword	/sˤid/	you hunt	/sˤi:d/	you hunt
/sad/	he blocked	/sa:d/	it prevailed	/sˤad/	he went	/sˤa:d/	he hunted
/sud/	nonword	/su:d/	black (pl.)	/sˤud/	you hunt	/sˤu:d/	nonword

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الخصائص الصوتية الفيزيائية للحركات وأصوات المد العربية بعد الأصوات المطبقة والمنفتحة لدى متحدثي اللهجة النجدية

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المستخلص:

تصف هذه الدراسة الخصائص الصوتية الفيزيائية للحركات الفتحة والضمة والكسرة وأصوات المد الألف والواو والياء في العربية عند نطقها من قبل ناطقين باللهجة النجدية. وتقوم هذه الدراسة تحديداً بقياس الطول الزمني لهذه الأصوات وتردد نطاقها الرنيني الأول والثاني (F1-F2) ومقارنة الاختلاف الذي يطرأ عليها في سياقين مختلفين: بعد الأصوات المطبقة وبعد الأصوات المنفتحة. وشارك في هذه الدراسة أحد عشر شخصاً لغتهم الأم العربية النجدية من خلال قراءة مائة وأربع وأربعين كلمة تتضمن هذه الأصوات، وتم تسجيل أصواتهم وتحليلها باستخدام برنامج برات لتحليل الصوت فيزيائياً. وأظهرت النتائج اختلاف الحركات الفتحة والضمة والكسرة عن أصوات المد الألف والواو والياء في اللهجة العربية النجدية من حيث طولها الزمني وخصائصها (F1-F2).

الكلمات المفتاحية: اللهجة النجدية، الحركات وأصوات المد، الإطباق، الطول الزمني، الخصائص الصوتية