This article examined the effect of Modern Standard Arabic orthography on speech production quality (syllable stress and vowels) by 23 Arabic-speaking children with severe or profound hearing loss aged 8–12 years. Children produced 15 one-syllable minimal pairs of words that differed in vowel length (short vs. long) and 20 two-syllable minimal pairs differing in stress pattern. Each word was produced in three tasks: reading partially or fully vowelized words and imitation of aural stimuli. Results showed that fully vowelized words ensured vowel production: high-quality productions appeared on 99%, 74%, and 59% of productions on reading fully vowelized words, partially vowelized words, and on imitation, respectively. Moreover, correct vowel production affected correct consonant production. Correct production of stress was best on reading fully vowelized words, appearing on 54%, 21%, and 33% of productions for fully vowelized words, partially vowelized words, or imitation, respectively. Findings suggest the need to present fully vowelized written texts when teaching speech production to children with hearing loss. Such presentations enable more accurate productions that result in more intelligible speech.

Many deaf and hard-of-hearing individuals produce spoken language with typical voice and speech characteristics that result from their hearing loss. For example, individuals with hearing loss may omit or substitute consonants and neutralize vowels; they may use monotonous speech; and their voice may be characterized by inappropriate resonance, pitch, or intensity (Most & Frank, 1994; Smith, 1975). These segmental, suprasegmental, and voice-quality characteristics affect speech intelligibility (e.g., Monsen, 1983). The current paper will focus on the production of vowels and syllable stress.

Listeners perceive the vowels in speech mainly through acoustic information on the first two formants’ relations (Borden, Harris, & Raphael, 1994). In general, individuals with severe and profound hearing loss perceive the vowel /a/ and the vowel /u/ with more accuracy than other vowels because /a/ is stronger than the other vowels and /u/ is cued by relatively low frequencies, which are more audible to this population (Boothroyd, 1984). Research has shown that the perception of vowel height (e.g., /a/ vs. /i/ or /u/) was accomplished even by individuals with profound hearing loss using hearing aids (Boothroyd, 1985). The author argued that the participants succeeded due to intensity information that distinguished between these vowels. Interestingly, however, Hebrew-speaking individuals with cochlear implants perceived vowel place better than vowel height (Kishon-Rabin et al., 2002). The authors claimed that this finding probably resulted from some interaction between the acoustics of Hebrew (reduced number of vowels; Most, Amir, & Tobin, 2000) and the implant processing strategy.

With regard to vowel production, individuals with severe to profound hearing loss usually do not omit vowels but rather substitute them (Gold, 1980). Vowel substitutions are caused by general articulatory imprecision, which may result from the minimal sensory feedback offered to the speaker on the fine articulatory
adjustments. Substitution of a more central or neutral vowel for the intended one is one of the most frequent types of vowel substitution. Individuals with hearing loss generally tend to produce a neighboring but more central vowel instead of the target one. At the extreme, they neutralize all vowels, meaning that they produce a schwa with neutral quality instead of the other vowels. Another common substitution occurs when the speaker produces one member of a tense/lax vowel pair to substitute for the other (Smith, 1975). In general, research reported that cochlear implantation improved vowel production (Kishon-Rabin, Taitelbaum, Tobin, & Hildesheimer, 1999; Smith, Murdoch, McCormack, & Marshall, 1991). As with vowel perception, the vowel production of implanted Hebrew-speaking children showed that the vowel place contrast was produced with the most accuracy.

The accurate production of vowels is crucial for speech understanding. In fact, research has shown that as a result of coarticulation in speech production, the correct vowel production has an effect on consonant production as well (Osberger, 1978; Rubin-Spitz, 1984).

Listeners perceive syllable stress based on the time–energy envelope of the speech signal and/or its fundamental frequency information. The stressed syllable (as in ‘rebel vs. re’bel) is characterized by higher fundamental frequency, longer duration, and greater amplitude in comparison to the same but unstressed syllable (Borden et al., 1994).

Inasmuch as the stress syllable is cued by duration, amplitude, and fundamental frequency information, various researchers have claimed that many individuals with hearing loss should be able to perceive it (e.g., Boothroyd, 1984). Nevertheless, research findings are not consistent. Some researchers (Jackson & Kelly, 1986; Osberger & McGarr, 1982) reported that individuals with hearing loss often experience difficulties in perceiving the stress pattern. Rubin-Spitz and McGarr (1986) found that participants with severe or profound hearing loss succeeded in perceiving the stress pattern only in those stimuli where the stressed and unstressed syllables differed in amplitude. In a recent study, Most and Peled (2007) reported that stress was perceived significantly more poorly by children with cochlear implants in comparison to children with severe to profound hearing loss who wore hearing aids. Most and Peled claimed that this finding might have resulted from the fact that perception of stress relies on low frequency and temporal information, and the implant does not provide sufficient information to the listener regarding these cues (Henry & Turner, 2003; Kong, Stickney, & Zeng, 2005). In a previous study, Most (1999) reported a 80.3% success rate in perceiving syllable stress among Hebrew-speaking participants with severe or profound hearing loss who wore hearing aids.

Research has shown that the production of syllable stress by individuals with hearing loss may be characterized by either a uniform stress on all syllables or by stressing the inappropriate syllable (Most, 1999). The latter phenomenon may convey a different meaning than intended, whether in English (‘object–object), Hebrew (‘boker [morning]–boker [cowboy]), or Arabic (‘āmal [camel]–āmaal [beauty]) (Al-Ani, 1970; Borden et al., 1994; Most, 1999).

**Orthographic Systems: Definitions and Types**

An orthographic system is a graphic representation of spoken sounds (Downing, Lima, & Noonan, 1992). Orthographies that are based on the alphabetic principle can be classified according to the transparency of grapheme–phoneme correspondence, that is, their orthographic depth. An orthography that unequivocally represents its phonology following simple grapheme–phoneme correspondences is considered shallow, whereas in a deep orthography the relation of orthography to phonology is more opaque (Frost, 1994). In the latter, some letters have more than one sound, for example, the letter “c” may sound like /s/ or /k/, and a number of phonemes can be marked by more than one symbol.

**The Arabic Language**

Arabic is characterized by “diglossia,” where two linguistic varieties of the same language are used for socially distinct functions (Azzam, 1989; Ferguson, 1959). The “high” variety, Modern Standard Arabic (MSA), a modern descendent of the language of the Koran (Islamic holy book), is used for writing and for formal speech functions, like religious sermons or news broadcasts. This prestigious variety is conceived...
as an elegant language shared by literate speakers throughout the Arabic-speaking world. The "low," colloquial variety, comprises a multitude of local and ethnic vernaculars that are used for everyday conversation (Almusa, 2003; Hudson, 2002; Kishon-Rabin & Rosenhouse, 2000; Levin, Saiegh-Haddad, Hende, & Ziv, 2007; Saiegh-Haddad, 2004, 2005). Between the two poles lies a third intermediary variety in the everyday colloquial style of learned people. This quasi-standard variety, used in quasi-formal oral linguistic interactions, is a simplified form of MSA and parallels the Educated Spoken Arabic variety proposed by Ennaji and Sadiqi (1994, p. 86).

The MSA alphabet consists of 28 letters that represent the 28 consonantal phonemes. Three of these letters also represent the three long vowels /aa/, /uu/, and /ii/, whereas short vowels /a/, /u/, and /i/ are represented through an optional system of superscripted diacritics. The Arabic orthography consequently has two optional forms, fully and partially vowelized. 

Fully vowelized orthography includes both letters and diacritics that practically represent all consonants and vowels and can be considered a shallow orthography. Partially vowelized orthography, which includes only letters so that short vowels are not represented, is hence considered a deeper orthography (Abu-Rabia, 1996, 1997; Azzam, 1989; Oren, 2001). Abu-Rabia (1997, 1999) and Azzam reported that many partially vowelized words are homographs, and therefore they can be read as different lexical items. The diacritics that mark the short vowels (in fully vowelized orthography) often clarify the correct pronunciation of the written word (Azzam, 1989).

The distinction between long and short vowels in MSA is very important for correct pronunciation and spelling because this language contains minimal pairs of words that differ from each other only by vowel length. Also, the syllable stress in MSA is determined by the syllable length, that is, by the vowel length.

Orthography, Reading, and Speech Production

Shallow orthographies have the advantage of ensuring a degree of efficiency in reading and writing processes (Frost, 1994, 1995). Shallow orthography can support a word recognition process that involves the printed word’s phonology. This occurs because the phonological structure of the printed word can be easily recovered from the print by applying a simple process of grapheme-to-phoneme conversion (Frost, 1994). Frost and Katz (1989) examined the effect of visual and auditory degradation on participants' ability to match printed to spoken words in English (deep orthography) and in the Serbo-Croatian language (shallow orthography). They showed that both visual and auditory degradation had a much stronger effect in English than in Serbo-Croatian, regardless of word frequency. The authors used an interactive model to rationalize the relationship between the orthographic and phonologic systems in terms of a connection between both systems at all of their levels. The language's relationship between spelling and phonology determined the structure of this connection: a simple isomorphic connection between graphemes and phonemes characterized the shallower Serbo-Croatian, in contrast to a more complex, many-to-one connection in the deeper English. Simple isomorphic connections between the orthographic and phonologic systems in shallower orthography enabled participants to restore both the degraded phonemes from the print (despite auditory degradation) and the degraded graphemes from the phonemic information (despite visual degradation).

Studies on Hebrew orthography, which shares similar rules in its fully orthographic representation to those of MSA (Oren, 2001), examined the role of Hebrew vowel diacritics on different aspects of reading. Shimron (1999) examined the contribution of vowel representation to sight word reading and reading comprehension among native Hebrew-speaking third graders. The results showed that vowels sped up word reading and improved reading comprehension. In another study, Shimron and Sivan (1994) investigated the reading speed and comprehension of two groups of skilled readers, native Hebrew speakers for whom English was their second language, and native English speakers for whom Hebrew was their second language. Both groups were asked to read two types of texts: Hebrew and English. The Hebrew texts included two versions of Hebrew orthography: vowelized and partially vowelized. In Hebrew, as in MSA, vowelized printed words are marked by letters and...
diacritics, whereas partially vowelized words are marked only by letters. The Hebrew letters represent all consonants but only some of the vowels; therefore, a partially vowelized word represents all consonants and a few, if any, vowels. Diacritics represent all vowels, thus a vowelized word represents all its consonants and vowels (see Share & Levin, 1999). Shimron and Sivan’s results revealed that comprehension of English did not differ from comprehension of vowelized Hebrew. In addition, reading time was faster and comprehension was better on vowelized than on partially vowelized Hebrew texts.

The effect of Arabic orthography on reading has received only sparse research attention. Abu-Rabia (1996, 1997) investigated the effects of vowel representation (shallow orthography) and context on reading accuracy. He asked poorly skilled and skilled participants to read aloud paragraphs, sentences, and words that were presented in fully vowelized and partially vowelized texts. The results of both studies showed significant reading improvement in the fully vowelized condition across all the stimulus materials among all participants. Thus, vowels served as good facilitators for skilled and poor readers, as shown in their performance with fully vowelized versus partially vowelized sentences.

Saiegh-Haddad (2005) examined the effect of orthographic and diglossic factors on reading fluency among kindergartners and first graders who were native speakers of the Palestinian Arabic vernacular spoken in the North of Israel. She examined how memory related to letter recoding speed and to reading fluency in shallow Arabic orthography (fully vowelized with diacritics). The results revealed strong relations among these variables. Saiegh-Haddad explained that reading in the shallow orthography of vowelized Arabic seems primarily responsible for the speed of converting grapheme to phoneme.

In sum, previous research exhibited the advantage of full orthographic representation on various aspects of reading. The current study aimed to expand this research on reading to the domain of spoken productions and to focus on a population at risk for speech unintelligibility. Children with hearing loss express difficulties in vowel production as well as syllable stress production. Indeed, interventions for these children emphasize improvement in the intelligibility of their spoken language. Inasmuch as the different vowels as well as the syllable stress in MSA may be fully represented in its orthographic system, we assumed that full representation would result in better production of these elements of the spoken language. Thus, the purpose of the present research was to examine the effect of the orthographic representation of the word on the production of vowels and syllable stress by Arabic-speaking children with hearing loss. To examine the contribution of the full orthographic representation, children’s speech intelligibility was assessed using three tasks: imitation of words that were presented auditorily, reading of fully vowelized words, and reading of partially vowelized words. We also examined the effect of orthography on the production of adjacent consonants. Finally, the effect of the degree of hearing loss on speech productions was studied.

We hypothesized that the nature of the task would affect the production of the vowels and the syllable stress, with the best productions achieved through full orthographic representation. In general, we hypothesized that the long vowels (always marked through letters) would be produced better than short vowels. In addition, we expected that the vowels /a/ and /aa/, which are easier to produce, would be produced better than the vowels /i/, /ii/, /u/, and /uu/. We also predicted that the quality of vowel production would be linked to the quality of production for adjacent consonants. Finally, we hypothesized that a negative correlation would emerge between degree of hearing loss and the production of speech.

Method

Participants

Twenty-three native Arabic-speaking children with hearing loss participated in the study. All the children used the same Arabic-Spoken Vernacular and were exposed to MSA at school. See Table 1 for demographics of the sample.

Stimulus Materials

Two sets of words in MSA were used: 15 one-syllable /CVC/ minimal pairs of words to assess vowel production and 20 two-syllable minimal pairs of words to assess
syllable stress production. The two sets of pairs appear in the Appendix, along with their meaning in English, their phonetic transcription, and their MSA representation. Note that MSA, quasi-standard Arabic, and the Arabic-Spoken Vernacular, which were all used by all our participants, share lexical items. Hence, all the words we used belong to the MSA or quasi-standard Arabic, but some of these words also appear in the Spoken Vernacular.

The 15 one-syllable minimal pairs differed in their vowel length: one member of each pair contained the corresponding long vowel. Five pairs included the short vowel /a/ and the long vowel /aa/, five pairs included the short vowel /u/ and the long vowel /uu/, and five pairs included the short vowel /i/ and the long vowel /ii/. For each vowel, there were three pairs of words and two pairs of pseudowords. The complete list of stimuli appears in the Appendix.

The 20 two-syllable minimal pairs differed in position of stressed syllable. One member of each pair stressed the first syllable (e.g., ‘ba’nat—built) and the other member stressed the second syllable (e.g., ba’naat—girls). Five pairs included the stressed syllable containing the target vowel /ii/ versus the unstressed syllable containing the target vowel /i/; five pairs included the stressed syllable with /uu/ versus the unstressed syllable with /u/; and 10 pairs differed in stress regarding the vowel /a/ versus /aa/. Likewise, for the /ii/ versus /i/ and the /uu/ versus /u/ contexts, there were three pairs of words and two pairs of pseudowords each. For the /a/ versus /aa/ context, there were six pairs of words and four pairs of pseudowords. The complete list of stimuli appears in the Appendix.

Each word was printed twice, on two separate cards, once fully vowelized and once partially vowelized, thus comprising a total of 140 written cards (35 pairs × 2 vowelization formats). The standard font and letter size for MSA were used, as printed in schoolbooks.

Procedure

Each child was tested individually in a quiet room in the school in one session lasting between 1.5–2 hr. The children used their sensory aids, which were checked prior to the session to assure their appropriate functioning. The examiner presented the children with all 70 words (35 pairs) three times, once for each of the three tasks: imitation of auditory stimuli, reading of fully vowelized words, and reading of partially vowelized words. The order of the words within each task varied randomly across children, as did the sequence of the three tasks across children. A few practice items were used before each task to clarify the task. An electric microphone, 10 cm from the child’s mouth, and Sony M-800V microcassette audiotape recorder were used to record the children’s speech.

Table 1 Demographics for Arabic-speaking children (n = 23) with prelingual sensorineural hearing loss

| Gender | 16 boys, 7 girls |
| Age | 8–12 years (M = 8.87, SD = 1.57) |
| Class | Grades 3, 4, 5 |
| Hearing loss level | n = 10 (7 boys, 3 girls): severe hearing loss in the range of 50–80 dBHL (M = 60.50, SD = 10.12) |
| | n = 13 (9 boys, 4 girls): profound hearing loss in the range of 80–109 dBHL (M = 88.38, SD = 6.52) |
| Age of rehabilitation onset | 1–5 years |
| Sensory aids | n = 17: hearing aids |
| Cochlear implants | n = 5: cochlear implants |
| Main communication mode | n = 1: none |
| Implantation: at age 4–7 years | Duration of implant use: <1–5 years |
| | n = 6: spoken language |
| | n = 17: simultaneous (speech and sign) |
| Inclusion | Individually included in a class of hearing children according to child’s academic level; all of them studied together part of the time, as a special group |
| Speech/language lessons | One individual lesson weekly |
| Additional handicaps | None |
| Parents’ hearing status | All hearing |
| Child’s reading level | All had acquired reading, according to teacher reports |

Table 1 continued

| Speech/language lessons | One individual lesson weekly |
| Additional handicaps | None |
| Parents’ hearing status | All hearing |
| Child’s reading level | All had acquired reading, according to teacher reports |
productions for later assessment. In the imitation task, the examiner asked the child to repeat each word as it was spoken. The experimenter was seated facing the child and pronounced the words at a normal conversational level (72 dBSPL at the child’s seat). In the partially and fully vowelized tasks, the printed cards were displayed one at a time on the table, and the child was asked to read them.

Data thus comprised 70 productions (30 one-syllable words and 40 two-syllable words) for each of the three tasks by each of the 23 participants. All 4,830 of the recordings (70 words \times 3 tasks \times 23 children) were evaluated separately by two young adult listeners who were asked to write the word that they heard. The experimenter compared the responses of the two listeners, and for those words that elicited disagreement (292 productions, comprising 6%), a third listener was recruited.

**Results**

The means comprised the productions of the words and pseudowords together because analyses that were conducted for each type of stimulus separately revealed the same trends for these two types of stimuli. Table 2 presents the means and standard deviations of the percent correct production of the short and long vowels and consonants in initial and final positions. Table 3 presents the \(F\), \(p\), and \(\eta^2\) values for the main effects and interactions.

### Table 2

| Task                  | Short vowel | Long vowel |
|-----------------------|-------------|------------|
|                       | One-syllable word, \(M\) (\(SD\)) | Two-syllable word, \(M\) (\(SD\)) | One-syllable word, \(M\) (\(SD\)) | Two-syllable word, \(M\) (\(SD\)) | Total, \(M\) (\(SD\)) |
| Short and long vowel production |             |            |             |             |            |
| Fully vowelized       | 99.00       | 99.00      | 99.00       | 99.00       | 99.00      |
| Partially vowelized   | 35.36 (16.38) | 42.83 (17.24) | 72.75 (21.55) | 83.91 (15.80) | 58.71 (13.12) |
| Imitation             | 77.68 (21.42) | 67.83 (25.17) | 81.16 (23.06) | 70.43 (30.67) | 74.28 (23.12) |
| Production of consonants in initial position, preceding short and long vowels |             |            |             |             |            |
| Fully vowelized       | 55.65 (29.24) | 70.00 (29.92) | 65.80 (29.70) | 73.04 (27.58) | 66.12 (28.27) |
| Partially vowelized   | 47.54 (28.31) | 61.30 (30.57) | 56.81 (27.92) | 69.56 (27.71) | 58.80 (27.28) |
| Imitation             | 43.48 (31.71) | 54.35 (31.20) | 51.59 (33.16) | 55.65 (33.11) | 51.27 (30.89) |
| Production of consonants in final position, following short and long vowels |             |            |             |             |            |
| Fully vowelized       | 71.88 (31.07) | 75.65 (28.50) | 76.23 (29.80) | 76.30 (28.13) | 75.02 (28.87) |
| Partially vowelized   | 54.49 (33.25) | 63.48 (30.50) | 63.77 (33.86) | 67.17 (29.76) | 62.23 (31.07) |
| Imitation             | 58.26 (32.82) | 52.83 (33.02) | 53.91 (35.16) | 56.30 (35.17) | 55.33 (33.03) |

### Table 3

| Variable                     | Short and long vowels | Consonants in initial position | Consonants in final position |
|------------------------------|-----------------------|--------------------------------|-------------------------------|
|                              | \(F\) | Partial \(\eta^2\) | \(F\) | Partial \(\eta^2\) | \(F\) | Partial \(\eta^2\) |
| Task                         | 1, 22 | 11.48* | .34 | 2, 44 | 28.82*** | .57 | 2, 44 | 43.73*** | .67 |
| Word structure               | NS |                   | 1, 22 | 42.03*** | .66 | 1, 22 | 4.90* | .18 |
| Vowel length                 | 1, 22 | 104.03*** | .83 | 1, 22 | 26.46*** | .55 | 1, 22 | 7.15* | .25 |
| Task \(\times\) word structure | 1, 22 | 29.44*** | .57 | NS |                   | 2, 44 | 4.05* | .16 |
| Task \(\times\) vowel length | 1, 22 | 104.03*** | .73 | NS |                   | 2, 44 | 3.56* | .14 |
| Word structure \(\times\) vowel length | NS |                   | 1, 22 | 7.37* | .25 | NS |                   |     |
| Task \(\times\) word structure \(\times\) vowel length | NS |                   | NS | 2, 44 | 7.10** | .24 |     |       |

\(* p < .05, ** p < .01, *** p < .001.\)
Production of Short and Long Vowels

The upper part of Table 2 presents the means and standard deviations of the percent correct production of the short and long vowels in the one- and two-syllable words, within the three tasks. Note that, for reading of fully vowelized words (where both letters and diacritics were represented in the print), 99% of the productions were successful; therefore, they were not included in the statistical analysis. Thus, for the other two tasks, three-way analysis of variance (ANOVA) with repeated measures was conducted to examine the effect on vowel production of 2 (task: reading partially vowelized words where diacritics were missing in the print or imitation of words that were presented auditorily), 2 (word structure: monosyllabic or bisyllabic), and 2 (vowel length: short or long). Bonferroni post hoc tests were performed to find the sources of significant differences. Results (see Table 3 for the data) revealed a significant effect for task indicating that vowel production was more often accurate in imitation than in word reading of partially vowelized items. A significant effect for vowel length also emerged, indicating that children produced the long vowels better than the short vowels.

Two significant interactions also emerged. First, a significant interaction emerged between task and word structure. In the imitation task, children succeeded better with one-syllable than two-syllable words, whereas no such difference emerged for the reading of partially vowelized words task. The second significant interaction was between task and vowel length. The production of short vowels was less often accurate than that of the long vowels in the partially vowelized task but did not differ statistically in the imitation task.

No significant effect emerged for word structure, and no significant interactions emerged between word structure and vowel length or between task, word structure, and vowel length ($p > .05$).

Production of Consonants

We expected a link between quality of consonant production and quality of production of vowels. We examined this hypothesis for consonants in the initial position as well in the final position.

Initial consonants. The middle part of Table 2 presents the means and standard deviations of the percent correct productions of consonants in the initial position of one- and two-syllable words, preceding short and long vowels in the three tasks: imitation and reading of partially and fully vowelized words. Three-way ANOVA with repeated measures was conducted to examine the effect on initial consonant production of 3 (task: imitation, fully or partially vowelized), 2 (word structure: monosyllabic or bisyllabic), and 2 (vowel length: short or long). Bonferroni post hoc tests were performed.

The analysis revealed (see Table 3 for the data) significant effects for task, for word structure, and for vowel length. These results indicated that consonant production decreased from reading fully vowelized words, to reading partially vowelized words, and further to the imitation task. Consonant production was also better in bisyllabic than in monosyllabic words and prior to long than to short vowels. The significant interaction between word structure and vowel length indicated that the better production of consonants prior to long vowels reached significance on monosyllabic but not on bisyllabic words.

Final consonants. The lower part of Table 2 presents the means and standard deviations of the percent correct productions of the consonants in the final position of one- and two-syllable words, following short and long vowels in the three tasks. Three-way ANOVA with repeated measures was conducted to examine the effect on final consonant production of 3 (task: imitation or reading fully or partially vowelized words), 2 (word structure: monosyllabic or bisyllabic), and 2 (vowel length: short or long). Bonferroni post hoc tests were performed.

The analysis revealed (see Table 3 for the data) significant main effects for task, for word structure, and for vowel length. Overall, consonant production decreased in quality from reading fully vowelized words, to partially vowelized words, and further to the imitation task ($M = 75.02$ vs. $62.23$ vs. $55.33$, respectively). Consonant production was better in bisyllabic than in monosyllabic words and following long than short vowels.

Two-way interactions emerged between task and word structure and between task and vowel length.
Finally, a three-way interaction of task, word structure, and vowel length emerged. These interactions reflected the following picture: on reading fully vowelized words as well as on imitation, no differences emerged in production of consonants embedded in different word structures or following different vowels. On reading partially vowelized monosyllabic words, production of consonants after a long vowel was better than after a short vowel. Consonants after short vowels were produced better in bisyllabic words than in monosyllabic words.

Effect of Vowel Identity

We examined the effect of the specific vowels on productions. Table 4 presents means and standard deviations of the percent correct scores for the different vowels in reading fully vowelized words, reading partially vowelized words, and imitation of aurally presented words. Three-way ANOVA with repeated measures was conducted to examine the effect on vowel production of 2 (task: imitation or reading partially vowelized words), 2 (vowel length: short or long), and 3 (vowel identity: /a/–/aa/ or /i/–/ii/ or /u/–/uu/). Bonferroni post hoc tests were performed. The productions of vowels in reading the fully vowelized words were not included in the analysis because they reached 99.9%.

Table 5 presents the $F$, $p$, and $\eta^2$ values for the main effects and interactions. Significant main effects emerged for task, for vowel length, and for vowel identity. Vowel production was better in the imitation task than in reading partially vowelized words. Long vowels were produced better than short vowels. The vowels /a/ and /aa/ were produced better than /i/ and /ii/ and better than /u/ and /uu/, the last two not differing from each other.

Production, Hearing Loss, and Sensory Aids

The correlations between the degree of hearing loss and the correct productions of the vowels and consonants were examined. Table 6 presents the means,
standard deviations, and Pearson coefficients. Significant, negative, high correlations were obtained between the degree of hearing loss and the production of short vowels as well as the production of consonants. Only moderate negative correlations emerged between the degree of hearing loss and the production of long vowels. Thus, in general, as hearing loss increased, production was poorer, particularly on short vowels and consonants.

Finally, we examined the effect of the sensory aid and the degree of hearing loss on the production of vowels and consonants. The participants were divided into three groups: 5 children with cochlear implants, 10 children with severe hearing loss in the range of 50–80 dBHL wearing hearing aids, and 8 children with profound hearing loss in the range of 80–109 dBHL wearing hearing aids. Table 7 presents means, standard deviations, and $F$ values of the percent correct production of the long and short vowels and the consonants in the three groups.

Two-way ANOVA with repeated measures revealed a significant main effect for group. The productions of children with profound hearing loss who wore hearing aids were poorest, whereas the two other groups—children with severe hearing loss wearing hearing aids and children wearing cochlear implants—did not differ from each other. The analysis also revealed significantly better production of long vowels than of short vowels and consonants. Finally, a significant interaction emerged between group and vowel or consonant productions. The children with profound hearing loss succeeded much better in the production of long vowels compared to the short vowels and consonants, whereas these differences were less pronounced for the children with severe hearing loss and those with cochlear implants. Figure 1 presents the results of the interaction.

**Discussion**

This study examined the effects of MSA orthography on vowels and stress production by 8- to 12-year-old Arabic-speaking children with hearing loss. In other words, we investigated the contribution of orthographic print representations to these children’s speech intelligibility. The advantage of the fully vowelized over the partially vowelized representation has already been documented in Hebrew (Shimron, 1999) as well as in Arabic (Abu-Rabia, 1996, 1997, 1999). However, those earlier studies probed orthography’s effects on normally hearing children’s reading fluency, accuracy, and comprehension, whereas this article scrutinized effects on speech intelligibility among children with hearing loss.

The results of the current study, indeed, revealed that children’s production of vowels as well as their production of syllable stress were unequivocally better when these children with hearing loss were introduced to the full orthographic representation of a word, in comparison to their production of these elements when processing either deficient written orthography or a verbal representation of the word. The fully vowelized representation of the vowels resulted in better syllable stress production and also in better production of the adjacent consonants both prior to or following the target vowel. These findings likely result from the fact that, in the full orthographic representation, the exact phonological representation of the word leads to its clear and intelligible production. In the fully vowelized representation, the relations

**Table 5** $F$ values and partial $\eta^2$ for main effects and interactions

| Variable                        | $F$ ($p < .001$) | Partial $\eta^2$ |
|---------------------------------|------------------|-----------------|
| Task                            | 1, 22            | 10.43           | .32          |
| Vowel length                    | 1, 22            | 118.66          | .84          |
| Vowel identity                  | 2, 44            | 30.73           | .58          |
| Task $\times$ vowel length      | 1, 22            | 61.91           | .74          |
| Task $\times$ vowel identity    | 2, 44            | 12.39           | .36          |
| Vowel length $\times$ vowel identity | 2, 44   | 13.92           | .39          |
| Task $\times$ vowel length $\times$ vowel identity | 2, 44 | 12.17           | .36          |

* $p < .05$, ** $p < .001$.

**Table 6** Means, standard deviations, and Pearson coefficients between the degree of hearing loss and the correct productions of vowels and consonants across tasks

| Production     | $M$     | $SD$    | Range    | $R$      |
|----------------|---------|---------|----------|----------|
| Long vowels    | 77.07   | 15.39   | 35.83–95.42 | $-0.47^*$ |
| Short vowels   | 55.92   | 16.63   | 24.17–79.58 | $-0.83^{**}$ |
| Consonants     | 58.73   | 28.34   | 7.36–95.14 | $-0.80^{**}$ |

* $p < .05$, ** $p < .001$. 
between the graphemes and the produced phonemes are linear and simple. The effect of orthography on speech production was also apparent in reading partially vowelized words: Children produced long vowels, which are marked by letters in the spelling of partially vowelized words, better than they produced the short vowels that remain unmarked in this partial representation (Abu-Rabia, 1996, 1997).

Table 7  Means, standard deviations, and \( F \) values of the percent correct production of long and short vowels and of consonants in the cochlear implant group and the two hearing aid (HA) groups

|                  | Cochlear implant \((n = 5)\), \(M (SD)\) | HA: severe hearing loss, \(M (SD)\) | HA: profound hearing loss, \(M (SD)\) | Total, \(M (SD)\) | Group \(F\) partial \((2, 20)\) \(\eta^2\) | Letter type produced \(F\) partial \((2, 20)\) \(\eta^2\) | Interaction between group and letter type produced \(F\) partial \((4, 40)\) \(\eta^2\) |
|------------------|------------------------------------------|-------------------------------------|--------------------------------------|-----------------|------------------------------------------|------------------------------------------|------------------------------------------|
| Long vowels      | 84.83 (5.79)                             | 80.54 (13.37)                       | 67.86 (18.39)                        | 77.07 (15.39)   | 7.10**                                   | 27.73**                                  | 3.36*                                    |
| Short vowels     | 63.58 (11.57)                            | 64.96 (11.59)                       | 39.84 (12.87)                        | 55.92 (16.63)   | .42                                      | .58                                      | .25                                      |
| Consonants       | 65.72 (26.65)                            | 73.78 (23.82)                       | 35.56 (20.42)                        | 58.73 (28.34)   |                                          |                                          |                                          |

\(p < .05, **p < .001.\)

The results demonstrating better production of consonants, both initial and final, when introduced to fully vowelized words compared to imitation and partially vowelized words, and also when adjacent to long vowels compared to short vowels, support previous findings on the presence and the effect of co-articulation in speech production and specifically on the effect of vowel production on consonant production.

![Figure 1](https://academic.oup.com/jdsde/article-abstract/13/3/417/374450)

**Figure 1**  Interaction between hearing loss/sensory aid and vowel or consonant productions.
Children produced both vowels and consonants better in bisyllabic than in monosyllabic words, in reading partially vowelized words. This finding supported previous studies that reported better production of bisyllabic words (Kirk, Hay-McCutcheon, Sehgal, & Miyamoto, 2000; Kirk, Pisoni, & Osberger, 1995). Those researchers suggested that bisyllabic words were more distinct from each other and shared less similarity among them. In addition, they claimed that in bisyllabic words the producer benefits from language redundancy, which serves as another source of information in the production process. The relatively longer word consists of more phonemes, which may provide additional information with regard to the specific word’s linguistic meaning, thus enabling better speech production. In the current study, though, in the imitation task, monosyllabic words were produced better than bisyllabic words. This unexpected finding may be explained by the fact that the imitation task supplied both acoustic and visual information, lessening the need to depend on language knowledge. In other words, for the shorter words listeners appeared to rely on the sensory data, whereas for the longer words they relied on linguistic knowledge.

All the vowel types were produced correctly in reading fully vowelized words. However, when children read partially vowelized words, the /a/ and /aa/ vowels were better produced than the other vowels. This finding is in line with previous studies showing that /a/ and /aa/ are easier to produce (Fletcher, Dagenais, & Critz-Crosby, 1991). These vowels are lower with respect to tongue height and require less tongue manipulation than the other four vowels, which all require the speaker to raise the tongue either at the front or back (Borden et al., 1994). In addition, these lower vowels are stronger than the other vowels, which is significant when hearing loss is involved (Boothroyd, 1985).

In addition, in reading partially vowelized words, children produced the /i/ vowel better than /u/. Previous research reported that /u/ is produced better than /i/ by children with hearing loss as a result of the more audible acoustic cues (lower formants) for the vowel /u/, compared to the higher second formant of the vowel /i/ (Boothroyd, 1984). However, in the partially vowelized task, production did not depend on
auditory information (as in imitation), and thus this information was less relevant. On the other hand, previous research reported that the vowel /i/ is motorically easier to produce (Borden et al., 1994). Thus, in reading partially vowelized words, the ease of production appeared more dominant. No difference emerged in the production of the long vowels /ii/ versus /uu/, either on imitation or on reading partially vowelized words. Apparently, each task provided sufficient but different information—full orthographic representation or acoustic and visual information—that facilitated correct production. Thus, overall, the current results emphasize the role of print in speech learning, particularly the contribution of full orthographic representation to the spoken productions of all vowels.

Degree of hearing loss correlated negatively with vowel and consonant production. This finding supports previous research with various measures of speech production (Eisenberg, Martinez, & Boothroyd, 2001; Svirsky, Chin, Miyamoto, Sloan, & Caldwell, 2000). When the children were divided into three groups according to severity of loss (profound and severe) and type of sensory aid (hearing aids, cochlear implants), the production performance of children with profound hearing loss who had hearing aids was inferior to that of the children with severe hearing loss who had hearing aids and to that of the children with profound hearing loss who had cochlear implants. The children with severe hearing loss performed similarly to those with the cochlear implants, thus corroborating previous findings showing that implanted children manifest the superior auditory information that is accessed through the cochlear implant, which leads to better speech production (Blamey, Barry, & Jacq, 2001; Tobey, Geers, & Brenner, 1994). It should be noted that the children with profound hearing loss who had hearing aids produced the long vowels better than the short ones. This resulted in good production of syllable stress because in Arabic the syllable stress is produced with a long vowel. Thus, syllable stress, which listeners perceive through various acoustic cues including duration (Borden et al., 1994), is a speech feature that can be correctly perceived and produced even with very little amount of residual hearing (Frank, Bergman, & Tobin, 1987; Most, 1999).

In summary, the current study revealed that the presentation of fully vowelized print to children with hearing loss resulted in better production of vowels and, in turn, to better production of consonants. These outcomes suggest that remediation of speech production in individuals with hearing loss should involve a diversity of tasks that include reading. Very commonly, interventionists present speech materials either through imitation of auditory stimuli or through the use of visual stimuli such as pictures. Presentation of fully vowelized written materials, as in MSA with its letters and diacritics, may be more effective in eliciting better production of the target words and thus may result in better speech intelligibility. Future research would do well to expand and examine this phenomenon in other languages that share similar characteristics, such as Hebrew.

Appendix

Word-Pair Stimuli Used for Each of the Three Vowels

List 1: One-syllable minimal pairs (15) of words with differing vowel length

| Meaning | Phonetic transcription | Long vowel | Short vowel | Modern standard arabic |
|---------|------------------------|------------|------------|------------------------|
| **Vowels: /a/-/aa/ (5 pairs)** | | | | |
| Sew - line | xaat | XaT | خط - خاط | |
| Mouse - run away | faar | far | فرار | |
| Drive - tear | qaad | qad | قاد | |
| Pseudo words | naaw | naw | نو | |
| **Vowels: /u/-/uu/ (5 pairs)** | | | | |
| Bean - jasmine | fuul | Ful | فول | |
| Houses - pearls | duur | dur | دوور | |
| Garlic - mouth | Ωum | Ωum | توم | |
| Pseudo words | buud3 | bud3 | بو | |
| **Vowels: /i/-/ii/ (5 pairs)** | | | | |
| Jug - button | ziir | zir | زير | |
| Go - secret | siir | sir | سير | |
| The letter “s”-tooth | Siin | sin | سن | |
| Pseudo words | mik | mik | ميك | |
| Wiif | wif | ويف | |
List 2: Two-syllable minimal pairs (20) of words with differing syllable stress

| Meaning         | Phonetic transcription | Modern standard arabic |
|-----------------|------------------------|------------------------|
|                 | Stressed (long vowel) | Nonstressed (short vowel) |
| **Vowels: /a/-/aa/ (10 pairs)** |                       |                        |
| With/without stress on the second syllable (target vowel in second syllable) | | |
| Beauty - camel  | ɟa`maal               | ɟamal                  |
| Airport - rain  | ma`Taar               | maTar                  |
| Girls - she builds | ba'naat            | banat                  |
| Pseudo words    | li`kaan               | Lakan                   |
|                 | na`faaq               | nafaq                   |
| With/without stress on the first syllable (target vowel in first syllable) | | |
| World - flag    | `aalamz               | alamz                   |
| Name of boy – dates | `taamir            | `tamir                  |
| Boat - approach | `qaarib               | `qarib                  |
| Pseudo words    | `maasal               | masal                   |
|                 | faaalan               | falan                   |
| **Vowels: /u/-/uu/ (5 pairs)** | | |
| With/without stress on the second syllable (target vowel in second syllable) | | |
| Sheep - go crazy | xa`ruuf               | xaruf                   |
| Happiness - beds | su`ruur               | surur                   |
| Roses - veins   | wu`ruud               | wurud                   |
| Pseudo words    | tu`luun               | tulun                   |
|                 | mu`fuut               | mufut                   |
| **Vowels: /i/-/ii/ (5 pairs)** | | |
| With/without stress on the second syllable (target vowel in second syllable) | | |
| Patient - dream | ḥa`liim               | ḥalim                   |
| Short - palace  | qa`siir               | qasir                   |
| Big - grow      | ka`biir               | kabir                   |
| Pseudo words    | za`liid               | zalid                   |
|                 | da`miif               | damif                   |

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