How Should I Read This Word?: The Influence of Vowelization in a Deep Language Orthography on Online Text Comprehension

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Abstract. This study examined whether online text vowelization of words in context facilitates reading in Hebrew, which is a deep orthography language. The study compared the effect of vowelization on reading among native and non-native Hebrew speakers. In *Study 1*, 44 participants performed a self-paced reading - cumulative presentation task [9], that includes a 2 (voweled/non-voweled) X 2 (frequent/non-frequent) X 2 (homographs/unambiguous words) X 2 (location of words: beginning or middle/end of sentence) design. *Study 2* was conducted in order to deal with some of the methodological problems in study 1. Eighty-six participants performed the same task. Results indicated that vowelization does not facilitate reaction times of homographs for both Hebrew and non-Hebrew speakers. The results are discussed in relation to previous studies and the participants' characteristics.

1 Introduction

The rapid growth in present-day communication technologies has led to an accelerated shift in reading habits, from print to digital-online. Due to design and usability constraints that involve online reading, such as hyperlinks, scrolling and line-length, it is of great importance to improve readability and accessibility of online information, particularly (1) in deep orthography languages, which often lack correspondence between letters and sounds [5]; (2) in countries where multiple languages are spoken; and (3) for people with reading disabilities. The Hebrew language is an ancient deep-orthography language that uses a punctuation system (diacritical marks) which provides vowel information to improve readability and comprehension, especially for low-frequency words [7, 5], borrowed words [3], and homographic words – words that have more than one meaning in their unvoweled version [4]. Vowelization is most important for children at the early stages of learning Hebrew [11], for non-native Hebrew speakers, for individuals with reading difficulties [6,3], and when reading under time constraints. To date, most studies have tested the readability of single words. The effect of vowelization on the readability of words in context has not been tested or standardized.

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This series of studies examined the effect of online text vowelization of Hebrew words in context on reading, among native Hebrew speakers and speakers of Hebrew as a second language. Our hypothesis was that vowels would shorten reading latencies, especially in the case of low frequency words at the beginning of sentences (no context information). We expected this effect to be greater for non-native Hebrew speakers compared to native speakers.

We believe that results will facilitate the determination of criteria for vowelization and thus help improve online reading. In a country that unites individuals with a wide variety of language backgrounds (e.g. Arab-Israelis, immigrants from Russia and Ethiopia) and that stands at the forefront of technology, it is most important to create a readable, accessible and thus usable computerized environment. The characteristics of the Hebrew language enable us to examine the conditions under which vowelization may contribute to the minimization of on-line reading errors, which will allow the creation of such a computerized environment. These studies will contribute to our understanding of the impact of vowelization on readability, and provide guidelines for vowelization of online and offline texts. Results will also be helpful in facilitating reading of other deep languages, such as Vietnamese and Chinese that incorporate tones in their phonology to distinguish among words.

2 Literature Review

2.1 Hebrew Orthography

As of today, most Hebrew texts, both online and in print, are unvoweled. Voweled texts are used to facilitate reading, mainly in children's books, poetry, prayer books, and sacred scriptures. In special cases, it is common to vowel selected letters or words even in unvoweled texts. The major means of delivering vowel information in voweled words is by using diacritical marks – dots and minor strokes – placed below, inside or above the letters. In its unvoweled form, Hebrew is considered a "deep orthography" language. In deep orthography, the relation between spelling and sound is more opaque and letters may represent different phonemes in different contexts; moreover, different letters may represent the same phoneme [5].

2.2 Vowelization and Reading Comprehension

Navon and Shimron studied the effect of vowelization in the recognition of words [10, 13, 14]. They found that vowelized words were read significantly faster than unvowelized ones. This effect, however, became insignificant when context was added [14]. Koriat examined whether vowelization aids word recognition using a lexical decision task [7] and found that when vowelization was used between-subject factor, it has little effect on response latency. When reading low-frequency words, Koriat found that reading time of both voweled and unvoweled words decreased when context was provided [7]. Koriat concluded that the effect of context was additive to the effect of vowelization. Similar findings were obtained by Bentin and Frost [2] who also claimed that for fluent Hebrew speakers, the contribution of vowel signs in providing phonological information is limited. This claim was supported by Shimron [11]. In a series of experiments, Frost found that vowelization facilitates reading of phonologically ambiguous words [4]. More recently, Shimron found that vowel signs speed up recognition memory of words, and improve recall of words printed in the context of mixed lists [12]. Abu-Rabia found a significant positive effect of vowelization on the Hebrew readability for non-native Hebrew speakers [1].

The literature indicates that most studies tested the influence of vowelization on readability of *single words* only, rather than words in context. Thus, the effect of vowelization on readability is still ambiguous and the question of whether and under which circumstances vowelization facilitates reading latencies is still open. The current studies examined the effect of online text vowelization of words in context on readers of a language with deep orthography, using Hebrew as an example, focusing on homographic words. To date, no study has examined systematically the above questions by means of on-line reading techniques.

3 The Studies

This paper describes two separate studies. The purpose of both studies was to explore the effect of online text vowelization of Hebrew words in context on reading among Hebrew speakers and speakers of Hebrew as a second language. Study 2 replicated study 1, with methodological changes relating to the structure of the experiment.

3.1 Study 1

Method

Participants: 44 students at the Open University of Israel participated in the study as part of their requirements for a B.A. in Psychology. Participants included native Hebrew speakers (N=32) and speakers of Hebrew as a second language (N=12). The tasks were administered during one session at the Open University Psychology Lab during May-June 2007.

Tasks

Computerized task: Participants performed a self-paced reading - noncumulative presentation task [9], using a computer to present the stimuli.

Stimuli: Words were printed in a san serif digital 12-point Arial font, and were presented in their proper location in the sentence on the computer screen. Font-type and size selection were made according to most suitable characteristics for online reading [15]. The design included 2 (voweled/non-voweled) X 2 (frequent/non-frequent) X 2 (homographs/unambiguous words) X 2 (location of words: beginning, middle/end of sentence) creating 16 possible conditions.

Procedure: A series of 5 sentence segments composed of one word or more were projected on the screen, controlled by the participants. After the entire sentence was projected, the participants received a comprehension question that tested their understanding of the sentence and the words. Participants were instructed to read each word at a natural pace and to respond to the comprehension question as accurately as possible. The task consisted of one block of 160 trials: 80 sentences with ambiguous words (Experimental sentences) and 80 sentences used as fillers (Control sentences), half of which were voweled. The sentences were presented in random order. Prior to the beginning of the experiment, subjects were given instructions and eight practice trials in which feedback on their performance was given. Response times (RT) for reading each segment and the complete sentence were recorded, as well as the accuracy of their responses to the comprehension questions.

Demographic questionnaire: In order to collect data on participants' language background and reading skills, a demographic questionnaire was distributed.

Results and discussion

Accuracy: Table 1 shows mean accuracy on comprehension questions (no subjects were excluded from the analysis).

ANOVA (repeated measures) was calculated for 2 (homographs/unambiguous words) X 2 (voweled/non-voweled) X 2 (frequent/non-frequent) X 2 (beginning or middle/end of sentence) to examine differences within subjects and between groups on performance. Results revealed main effects for group: non-native speakers were less accurate than native speakers (84.5% vs. 90.1, respectively; $F(1,42)=12.8$, $p=.001$); for condition: control sentences were read more accurately than experimental sentences (89.7% vs. 87.5, respectively; $F(1,42)=9.175$, $p=.004$) and for location of target word: sentences were read more accurately when target word was at the end (89.5% vs. 87.7, $F(1,42)=5.322$, $p=.025$). Although main effects in accuracy were found (table 1), differences were minimal and accuracy rates for both groups were high; all participants read and understood the target sentences and responded correctly to the comprehension questions.

Table 1. Mean accuracy of responses to comprehension questions (N=44)

	Mean ACC (%)	SD
CHBN *	85.2	.076
CHBY	83.9	.097
CHEN	93	.086
CHEY	95	.079
CLBN	86.8	.107
CLBY	88.2	.092
CLEN	92	.089
CLEY	93	.085
EHBN	93	.098
EHBY	91	.107
EHEN	84.8	.102
EHEY	85.2	.093
ELBN	86.6	.109
ELBY	86.6	.104
ELEN	86.4	.116
ELEY	86.4	.1036

* C/E: Control vs. Experimental condition – H/L - High vs. Low frequency word.
B/E - Target word at the Beginning vs. End of sentence – Y/N - Vowelization - Yes or No.

Reaction Times

Data analysis: Only trials in which accuracy was 100% were included in the RT analysis. Trials in which response times were greater than 200 msec or shorter than 2000 msec (2 sec) were removed from the analysis. Analysis included control and experimental sentences. No subjects were excluded from the analysis. ANOVA (repeated measures) was calculated to examine differences in RT within subjects and between groups. Results revealed 5 main and marginal effects and 4 interactions:

1. Main effect for group: Hebrew speakers read the sentences faster than non-Hebrew speakers (592.71 vs. 745.2, respectively; F(1,42)=15.48, p=.000).
2. Main effect for frequency: sentences which contained high frequency words were read faster than low frequency words (691.86msec vs. 725.35, respectively; F(1,42)=29.14, p=.000).
3. Main effect for location: when target words were located at the beginning of the sentence, the sentence was read faster than when they were in the middle or end (678.69 msec vs. 738.52, respectively; F(1,42)=83.181, p=.000).
4. Marginal effect for condition: control sentences were read somewhat faster than experimental sentences (703.66msec vs. 713.54, respectively; F(1,42)=4.204, p=.047).
5. Marginal effect for vowelization: non-vowelized target words were read faster than vowelized target words (701.98 msec vs. 715.22, respectively; F(1,42)=4.393, p=.042). No interaction between group and vowelization was found. The difference in RT between low and high frequency words was greater for non-native Hebrew speakers (828.44msec vs. 781.34; F(1,42)=4.81, p=.034), whereas for Hebrew speakers there was almost no difference (622.26msec vs. 602.37).
6. Whereas native Hebrew speakers were almost not affected by the location of the target word (592.62msec vs. 632.01 when target word was presented at the beginning of the sentence compared to the end of it), RTs for non-native Hebrew speakers were longer when the target word was at the end of the sentence compared to the beginning of it (845.03msec vs. 764.74, respectively) (F(1,42)=9.718, p=.003).
7. The difference in RT between high and low frequency words was larger in the control sentences than in the experimental sentences (F(1,42)=8.002, p=.007). High frequency words in the control sentences were read faster than in the experimental sentences (M=679.47msec vs. 704.24, respectively). In contrast, when reading low frequency words, RT was almost the same in both experimental sentences (M=722.84) and control sentences (727.86).
8. The location of a target word had a differential effect on RTs of control and experimental sentences. When a target word was presented at the beginning of the sentence in both control and experimental sentences it affected RTs less for both native and non-native Hebrew speakers (F(1,42)=20.208, p=.000, M=687.36msec vs. 670.01, respectively). However, when the target word was presented at the end of the sentence it had more impact on RT, depending on the sentence type: RTs were higher in the experimental than in control sentences (M=757.08msec vs. 719.96, respectively).

The main finding of study 1 was that overall, vowelized words were read more slowly than non-vowelized words, for both groups. Other findings can be summarized as follows:

1. Both native and non-native speakers had high accuracy rates for comprehension.
2. Overall, non-native speakers are slower in reading Hebrew than native speakers.
3. In general, high-frequency words were read faster than low-frequency words, however for the non-native Hebrew speakers, frequency of words affected reading latencies more than for native Hebrew speakers.
4. Control sentences were read faster overall. However, when a target word was presented at the beginning of the sentence, it affected reading latencies less than when it appeared at the end of a sentence for both native and non-native speakers.
5. Target words at the end of the sentences were read faster than at the beginning and this effect was larger for non-native speakers.

The main hypothesis of study 1 was that vowels would shorten reading latencies, especially in the case of low frequency words at the beginning of sentences (no context information) and for non-native speakers. We did not find such an effect in the current study. We found that non-vowelized target words were read faster than vowelized target words for both groups. We suggest several alternative explanations. First, the number of participants in the groups was not equal (32 native vs. 12 non-native), which may affect effect sizes. Second, 4 of the 12 non-native speakers were speakers of Arabic who were born in Israel. The rest were native Russian speakers who had been living in Israel for over 12 years. All were at least second-year university students and thus may have been more familiar with unvowelized than with vowelized text in Hebrew. Third, target words were vowelized in all syllables. It is possible that too many vowels in a word create a redundancy effect that interferes with the reading process. Thus, it may be that one vowelized syllable (or the minimal number of syllables for distinguishing between the various alternatives) would not only be sufficient for reading and understanding the word, but would also facilitate reading and thus reading latencies would shorten. Finally, in order to conceal the purpose of the experiment from the participants, we vowelized two additional words in each vowelized sentence. Although these words were chosen based on their minimal length, thus requiring fewer vowels, this may have made reading latencies longer. Study 2 was conducted to deal with methodological issues relating to the structure of the experiment as described above.

3.2 Study 2

Method

Participants: 86 students at the Open University of Israel participated in the study as part of their requirements for a B.A. in Psychology. Participants included native Hebrew speakers (N=76) and speakers of Hebrew as a second language (N=10). The tasks were administered during one session at the Open University Psychology Lab during July-October 2008.

Tasks: The design of study 2 was similar to study 1 with the following changes in the self-paced reading - noncumulative presentation task [9]: (1) Each sentence contained 3 segments instead of 5; (2) In each target word, we vowelized either one syllable or the minimal number of syllables that distinguished between the reading alternatives; and (3) To conceal the purpose of the experiment from the participants, we vowelized only one additional non-target word in each sentence.

Results

Accuracy: Table 2 shows mean accuracy on the comprehension questions (no subjects were excluded from the analysis). ANOVA (repeated measures) was calculated for 2 (homographs/unambiguous) X 2 (voweled/non-voweled) X 2 (frequent/ non-frequent) X 2 (beginning or middle/end of sentence) to examine differences within subjects and between groups. Results revealed main effect for group: non-native Hebrew speakers were less accurate compared to native speakers (89.4% vs. 85.5, respectively; F(1,84)=6.48, p=.013, partial Eta squared (h_p^2)=.072). Main effect for condition: control sentences were read more accurately than experimental sentences (88.7% vs. 86.2, respectively; F(1,84)=9.094, p=.003, partial Eta squared (h_p^2)=.098). Main effect for location of the target word: when target word was at the end sentences were read more accurately than when target words were at the beginning (88.8% vs. 86.1, respectively; F(1,84)=10.429, p=.002, partial Eta squared (h_p^2)=.11). Although main effects in accuracy rates were found, differences were minimal as seen in Table 2, and accuracy rates for both groups were high; all participants responded correctly to the comprehension questions.

Reaction Times

Data analysis: Only trials in which accuracy was 100% were included in the RT analysis. Trials in which response times were greater than 200 msec or shorter than 2000 msec (2 sec) were removed. Separate analyses were conducted for all sentences and for only experimental sentences.

Table 2. Mean accuracy of responses to comprehension questions (N=86)

	Mean ACC (%)	SD
CHBN *	84	.093
CHBY	85	.09
CHEN	95.5	.066
CHEY	95.6	.064
CLBN	88.5	.096
CLBY	88.6	.11
CLEN	92.7	.095
CLEY	93	.082
EHBN	89.9	.088
EHBY	91.9	.085
EHEN	86	.107
EHEY	87.2	.099
ELBN	85.9	.101
ELBY	86.3	.109
ELEN	86.5	.105
ELEY	85.8	.116

* C/E: Control vs. Experimental condition – H/L - High vs. Low frequency word.
B/E - Target word at the Beginning vs. End of sentence – Y/N - Vowelization - Yes or No.

(1) All sentences: ANOVA (repeated measures) was calculated to examine differences in RT within subjects and between groups. Six subjects were removed from the analysis (native speakers – N=71, non-native speakers – N=9). Results revealed 4 main effects and 4 interactions:

1. Main effect for group: native speakers read faster than non-native speakers (827.3 vs. 974.2, respectively; F(1,78)=10.62, p=.000, partial Eta squared (h_p^2)=.12).
2. Main effect for frequency: sentences with high frequency words were read faster than low frequency words (880.12msec vs. 921.2, respectively; F(1,78)=29.36, p=.000, partial Eta squared (h_p^2)=.273).
3. Main effect for location: when target words were at the beginning of the sentence, the sentence was read faster than when they were in the end of the sentence (678.69 msec vs. 738.52, respectively; F(1,78)=87.36, p=.000, partial Eta squared (h_p^2)=.528).
4. Main effect for condition: control sentences were read faster than experimental sentences (868.9msec vs. 932.4, respectively; F(1,78)=70.16, p=.000, partial Eta squared (h_p^2)=.474).
5. Whereas the difference in RTs when reading control vs. experimental sentences was only 50msec in native speakers (804.7msec vs. 849.8 when reading control vs. experiments sentences, respectively), it was almost double in non-native speakers (933.2msec vs. 1015,; F(1,78)=5.86, p=.018, partial Eta squared (h_p^2)=.07).
6. Reading low frequency words was the hardest for non-native speakers compared to high frequency words (945.9msec vs. 1002.2), whereas for native speakers the difference in reading low and high frequency words was smaller (814.3msec vs. 840.3, respectively) (F(1,78)=3.97, p=.05, partial Eta squared (h_p^2)=.048).
7. Whereas there was almost no difference in RTs when reading high vs. low frequency words in experimental sentences (922.7msec vs. 942.1, respectively) the difference in RTs when reading high vs. low frequency words was larger in control sentences (837.5msec vs. 900.3, respectively) (F(1,78)=7.73, p=.007, partial Eta squared (h_p^2)=.09).
8. The difference in RTs when reading sentences in which the target word was at the beginning and end of the sentences was smaller in control sentences (847.67msec vs. 890.2, respectively) compared to experimental sentences (877.4msec vs. 987.4, respectively) (F(1,78)=21.33, p=.000, partial Eta squared (h_p^2)=.215).

(2) Experimental sentences: ANOVA (repeated measures) was calculated to examine differences within subjects and between groups. Four subjects were removed from the analysis (Hebrew speakers: N=72, non-Hebrew speakers: N=10). Results revealed 2 main effects and 2 interactions:

1. Main effect for group: Native speakers read the sentences faster than non-native speakers (852.3 vs. 1022.5, respectively; F(1,80)=13.58, p=.000, partial Eta squared (h_p^2)=.145).
2. Main effect for location: when target words were at the beginning of the sentence, the sentence was read faster than when they were at the end of it (877.8 msec vs. 996.9, respectively; F(1,80)=95.17, p=.000, partial Eta squared (h_p^2)=.543).
3. Whereas native speakers' RTs were affected less by the location of the target word (807.4msec vs. 897.1 when a target word was at the beginning of the sentence compared to at the end), non-native speakers were affected more by the location (948.2msec at the beginning vs. 1096.8 at the end) (F(1,80)=5.816, p=.018, partial Eta squared (h_p^2)=.068).
4. Vowelization had a differential effect on RTs depending on the location of the target word (F(1,80)=4.25, p=.042, partial Eta squared (h_p^2)=.05). Vowelization

improved reading when a target word was at the beginning of the sentence compared to the end of it (887.5msec vs. 948.4, respectively).When words were not vowelized the difference was even greater (868.1msec at the beginning of the sentence vs. 1009.5 at the end of the sentence).

The main hypothesis of study 2 was the same as that for study 1. The main finding of study 2 was that overall there was no difference in RTs when reading vowelized and non-vowelized words, both for native and non-native speakers, and additional findings were similar to the findings described in section 3.1 above. Possible explanations relate to the characteristics of the groups: unequal size and university students more familiar with unvoweled than voweled text. One interesting result is worth mentioning. In the second analysis (experimental sentences only), we found an interaction between condition and vowelization: vowelization improved reading when the target word was at the beginning of the sentence. However, non-vowelized words at the beginning of the sentence were read even faster compared to their vowelized forms. We believe this finding requires further investigation.

4 General Discussion

The main hypothesis of both studies was that vowels would shorten reading latencies, especially when reading low frequency words at the beginning of sentences and for non-native speakers. Based on Shimron [11], although reading voweled words may involve more information processing, we did not expect it to be more time consuming. In study 1, we found that non-vowelized target words were read somewhat faster than vowelized target words for both native and non-native speakers. In study 2 we found no difference between voweled and non-voweled text. These findings are in line with the arguments of Shimron and Navon [14]. In spite of the ambiguity in the literature regarding the effect of vowelization on readability, the current finding supports other scholars' notions regarding the role of vowel signs in Hebrew. For fluent Hebrew speakers, Bentin and Frost found that vowel signs provide limited phonological information [2]. Shimron claimed that reading the Hebrew alphabet is not impaired when vowel sounds are lacking [11]. Nevertheless, our findings contradict Abu-Rabia's findings of a significant positive effect of vowelization on Hebrew readability for non-native Hebrew speakers [1]. All other results of the current study are consistent with previous findings. As expected, non-Hebrew speakers have fewer years of experience with reading Hebrew and thus are slower in reading. In addition, low frequency words were read more slowly than high frequency words, consistent with previous findings [4]. When target words were at the beginning of the sentence, reading latencies were slower than when they were at the middle or end of a sentence. This may be due to the fact that when approaching target words at the middle or end of a sentence, context is already available and influences the reader's expectations regarding the upcoming word.

Note that in both studies, accuracy rates were high and similar, while RTs were longer for all conditions in study 2. The larger number of participants in the second study may more accurately reflect response times.

5 Future Research

We believe that future studies should examine different subjects. They should include (1) larger groups, especially of non-native speakers, (2) more recent immigrants with minimal exposure to unvowelized text in Hebrew, (3) young children in their first stages of learning to read, and (4) individuals with dyslexia [6].

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