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Reading different orthographic structures in the shallow-pointed Hebrew script: a cross-grade study in elementary school

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Abstract Hebrew-speaking children learn to read using a transparent, pointed writing system, but by grade three, they gradually begin using the non-pointed version of Hebrew script. The current study examined the development of reading, in the pointed script, of a nationally representative sample of children in grades two, four, and six. Rate and accuracy for four different pointed orthographic structures: letter-diacritic mark combinations, legal pseudowords, illegal pseudowords, and real words, were collected. Results show linear development for all structure types with respect to reading rate. In decoding real words and legal pseudowords, accuracy shows linear development. For illegal pseudowords and most of the letter-diacritic mark combinations, however, children in grades two and six were more accurate than those in grade four, indicating non-linear developmental trends. Results from this study support the need for both universal as well as orthography-specific models of reading development.

Keywords Accuracy · Diacritic marks · Hebrew orthography · Rate · Reading development

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Introduction

The past decade has seen reading research shift its focus to the study of reading processes in languages other than English. In a seminal paper, Share (2008) recently questioned the applicability of Anglophone findings to other languages and orthographies. Noting the high irregularity of English orthography, Share raised the possibility that findings based on English may not reflect the route of reading development in regular orthographies. In particular, he pointed out that the irregular nature of English drives a disproportionate focus on accuracy and a relative neglect of rate in the study of reading development. Furthermore, other important factors such as syntax, morphology, and semantics have often been overlooked in reading research, given the focus on phonology that has often characterized English-language studies.

It is clear that the roles of different aspects of reading vary in their importance and contribution to reading development based on the characteristics of specific languages. In some languages, reading research must take into consideration the existence of scripts with dual versions. Among these are the pointed variants, which are completely transparent (shallow), providing full phonological information, and the non-pointed (deep) variants, which provide incomplete phonological information, of Hebrew (Ravid, 2005; Share & Levin, 1999; Shimron, 1993), Arabic (Abu-Rabia & Taha, 2006), and Persian (Baluch & Besner, 1991). In Hebrew for example, children initially learn to read using the shallow pointed system and then transfer to reading the deep non-pointed version of the script. Due to this shift, a number of researchers have found it experimentally useful to use Hebrew for examining the role of phonological information in reading (Shimron, 1999). Within this context, however, little research has focused specifically on the developmental course through which children progress when learning to read Hebrew, particularly with respect to the role of phonological information that is very consistent at first and subsequently much less apparent. In addition, most of the work has focused on a between orthography comparison of script with and without diacritic marks. Less attention has been given to examining a within-script design that focuses on the role of diacritic marks for different orthographic structures at different points in reading development.

This study will examine the rate and accuracy of reading different orthographic structures of pointed script among Hebrew-speaking children in grades two, four, and six, thereby following their developmental transition from reading in a shallow, transparent orthography to reading in a deep orthography without diacritic marks.

Development of word reading

Ehri (Ehri, 1998; Ehri & Wilce, 1983) described three phases in the development of visual word recognition: an accuracy phase, an automaticity phase, and a speed phase, arguing that initially, children must acquire connections between representations of orthographic patterns and their phonological equivalents. During these early stages of reading acquisition, word identification may rely more on sublexical, phonological decoding operations than on direct (i.e., whole-word) lexical access.

Phonological recoding enables the learner to independently acquire an autonomous orthographic lexicon by serving as a self-teaching mechanism. Every successful decoding of novel letter strings provides orthographic knowledge regarding word-specific print-to-meaning connections (Share, 1995). Once these connections have been strengthened, the system can automatically process print in larger orthographical units, such as words, and then become faster at recognizing these units. In this paradigm, accuracy is universally assumed to precede rate in development (National Reading Panel, 2000). However, it is possible that the timing at which accuracy is acquired may differ among children learning to read in different orthographies.

There have been some recent demonstrations that learning to read an orthographically opaque script, such as French or English (Goswami et al., 1998; Landerl et al., 1997), is more difficult than learning to read a transparent orthography such as German (Wimmer & Hummer, 1990), Greek (Goswami et al., 1997), Italian (Thorstad, 1991), Spanish (Goswami et al., 1998), Turkish (Öney & Durgunoglu, 1997), or Welsh (Ellis & Hooper, 2001). In accordance, thanks to the transparent nature of the pointed version of Hebrew orthography, Hebrew-speaking children reach 80% accuracy in reading by the end of first grade (Geva et al., 1993; Share, 2004; Share & Levin, 1999). However, as in other orthographies with two scripts, Hebrew constitutes a special case in which learning to read pointed, transparent script is followed by learning to read the non-pointed, opaque script.

Pointed and non-pointed Hebrew scripts

The Hebrew orthography has three graphemic components. The first includes eighteen letters denoting consonants, five of which have an additional form used solely for word endings. The other components are the אהוי (AHWY) letter set, which denotes both consonants and vowels, and the pointing diacritics, termed *nikud* in Hebrew, which mainly denote vowels and stop/spirant alternation (e.g., *k/x*; Bar-On & Ravid,, in press). Diacritic marks are perceptually less salient than consonantal graphemes, as they constitute small dots and dashes placed under (בֶ), above (בֹ), or within (בּ) the letter (Ravid, 1996). The transparent, or shallow, pointed version of Hebrew supplies full phonological information by using both letter types as well as the nikud diacritics (Shimron, 1993), while the non-pointed version relies only on the two letter types and leaves out the diacritics.

The main information supplied by diacritic marks is vocalic. The merging of seven Classical Hebrew vowels to the five Modern Hebrew vowels resulted in homophony. The array of 13 diacritic marks represents the five vowels *a, e, i, o, u*. Three of them consist of a diacritic mark in combination with an AHWY letter, for example both גִי (GY) and גִ (G) represent *gi*, and three of them appear only under four letters representing pharyngeal consonants. One more diacritic called *schwa* marks vowel absence. Thus, each Modern Hebrew vowel has at least two, in some cases three, corresponding written signs. For example, the vowel *e* can be represented by each of three marks, appearing under the letters, as in the examples *séfer* (book) spelled סֵפֶר, and *emet* (truth), spelled אֱמֶת.

Diacritic marks also distinguish between the stop and spirant versions of the letters ב, כ, and פּ (B, K, and P). Thus, *kotev* (is writing) is spelled כּוֹתֵב with a dot (termed *dagesh*) inside the letter כּ (K) to mark the stop *k*, while *yixtov* (will write) is spelled יִכְתֹב without the dagesh, to mark the spirant *x* (Ravid, 2005). For a broader description of pointed Hebrew, see Ravid (2005).

As stated above, the opaque or deep, non-pointed orthographic version of Hebrew, the default version among non-novice readers, relies on letters alone to designate both consonants and vowels, with no nikud diacritics. Orthographic conventions dictate that consonantal representation of non-pointed words is full, except for stop/spirant distinctions. In contrast, vowels are only partially and ambiguously represented by the dual-function letters AHWY. Consequently, Hebrew readers face two major challenges in reading non-pointed words (Bar-On, 2010). The first involves the correct identification of a previously unfamiliar non-pointed written word. For example, when a young reader encounters the non-pointed word חתונה (ĦTWNH), pronounced *xatuna* (wedding), for the first time, it can be read, according to the orthographic conventions, as various non-words, such as *xetona*, *xatune*, or *xetone*. The second challenge involves solving the ambiguity embedded in homographic words. For example, the letter string מדבר (MDBR) can be read in several ways, such as *midbar* (desert), *medaber* (talking), and also *mi-dvar* (from the word of) and *mi-déver* (from the Bubonic Plague). While reading pointed script relies heavily on phonological processes, reading non-pointed script relies on morphological, syntactic, and semantic processing to fill in missing phonological information and solve ambiguity among homographic words (Ravid, 2005; Shimron, 1993).

Learning to read Hebrew—the long and winding road

The pointed version of Hebrew is used mainly for beginning instruction in grade one, where it is critical to systematically detect and convert all graphemes into phonemes and thereby achieve precise lexical identification (Bar-on & Ravid,, in press; Share & Levin, 1999). Despite the central role played by the diacritic marks in reading at this stage, they are hardly ever used by children in writing (Levin & Korat, 1993). School texts for grades two and three are still pointed, but children at these ages are simultaneously exposed to non-pointed text through media outlets including television and computers. By the end of their third year of school, children have generally mastered both the pointed and non-pointed systems. In grade four, most school-related and other texts are non-pointed, with the exception of biblical and literary texts (Shimron, 1999). Starting at this age, Hebrew readers abandon the pointed system, which becomes superfluous (Ravid, 1996). While most Hebrew readers cannot use the pointed system properly when writing, as they are unable to choose between the various marks representing a particular sound, they are able to read pointed text quite precisely (Shimron, 1993).

This expertise in the two systems has led many researchers to examine the contribution of phonological information (the presence of diacritic markings) to the orthographic identification of words. Findings from this line of research are contradictory and ambiguous. A number of studies show a minor advantage for single pointed words over non-pointed words, particularly with respect to words of lower frequency. However, this advantage has been shown to diminish and even disappear with the addition of context to the decoding task (Birnboim, 1995; Eshel, 1985; Koriat, 1984; Navon & Shimron, 1984). A similar finding has been described in Arabic (Abu-Rabia, 2001).

Shany and colleagues (Shany et al., 2006) compared reading of pointed and non-pointed words in a broad, nationally representative sample of Hebrew readers in grades two, four, and six. Findings regarding both rate and accuracy showed significant effects of grade level and task type (pointed versus non-pointed word reading) as well as an interaction between these two variables. In grade two, a significant gap was found between the task types, in favor of pointed words. Starting with grade four readers, this gap decreased and lost significance, such that pointed and non-pointed texts were read with similar success levels.

Other studies have shown that including diacritic marks in words does not increase the rate of their identification (Schiff & Ravid, 2004; Shimron & Sivan, 1994). Moreover, when a homographic non-pointed word was compared with a pointed alternative denoting the less common meaning (e.g., מלח, pronounced *melach* [salt] versus מַלָּח, pronounced *malach* [sailor]), the non-pointed word had an advantage (Bentin & Frost, 1987).

Additional studies have examined the contribution of diacritic marks to comprehension and memory of text, based on the assumption that faster processing of text would improve comprehension and memory. Here too, results have been ambiguous. Some have found diacritic markings to contribute to comprehension and memory of sentences (Shimron & Sivan, 1994), while others have found that this contribution is not unequivocal, and may be influenced by the type of task and by reading skills (Shimron, 1999).

Ravid (1996) asked students in grades one and four and a group of adults to read pointed and non-pointed sentences aloud. The sentences included linguistic constructions for which the accepted spoken form is different from the pointed form, which reflects their correct pronunciation based on linguistic rules. Children in grade one depended solely on the diacritic marks and thus read the pointed sentences as written, according to the linguistic rules. Children in grade four showed a complete disregard for the markings, reading the pointed sentences like the non-pointed sentences, as they would be spoken. Finally, the adults showed an increased ability to draw phonological information from the markings, although this slightly slowed their reading rates. In an additional study, which examined students in grades five, seven, ten, and eleven, as well as adults, using a similar method, students in grade eleven and adults utilized the markings, reading significantly more accurately than the three younger groups (Ravid & Shlesinger, 2001). These findings illustrate the winding path of pointed text—learned, forgotten, and relearned once again (Ravid, 2005).

The studies described above involved reading of meaningful words, the decoding of which can also be based on orthographic-lexical clues. To gain a fuller and more precise understanding of the way knowledge of the pointed system develops without these clues, it is necessary to use pure structures that do not enable the use of the clues, among them letter-diacritic mark combinations and pointed pseudowords that do not resemble acceptable structures in the language. Gur (2004) examined such pure structures in children still relying on the pointed reading system (grades one through three). However, this has not been explored in older children, who no longer use pointed script and usually read non-pointed script.

The current study is an in-depth examination of the development of knowledge regarding a system that is central and critical during the first stages of reading and becomes unnecessary and superfluous during later stages, beginning in the fourth grade. This study asked the following questions: (1) To what extent is knowledge of the pointed system retained in advanced stages of reading acquisition? (2) Which diacritic marks are more stable, and which tend to be forgotten?

These questions were explored using rate and accuracy measures regarding different orthographic structures among children of three grade levels: grade two, in which the acquisition stage of pointed reading comes to an end; grade four, which marks the transition from pointed to non-pointed reading; and grade six, in which students can read both systems.

Method

Participants

The original sample

The original sample of the present study was a two-stage stratified national representative sample. In the first stage, 52 schools were randomly selected from 1,164 regular schools in Israel and 20 more from 147 special education schools. From each school, one class was selected at each of three grade levels—two, four, and six. Thus, the special education population was overrepresented in the original sample (80% regular schools and 20% special education). In the second stage, children from both the regular and special education classes were randomly selected, after receiving written consent from parents. The final sample consisted of 461 children in grade 2 (379 from regular education; 82 from special education), 512 in grade 4 (388 and 124, respectively), and 511 in grade 6 (391 and 120). This sample of 1,478 children met the criteria of an unselected nationally representative sample, which was neither a clinical nor a teacher referral sample.

The sample of the present study

For the purposes of the present study, we first removed the special education children and then selected children in all grades who exhibited intact non-word decoding. Following a standard practice in the Hebrew literature (Breznits, 2002; Cohen-Mimran, 2006) the 16th percentile on an accuracy measure was used as a low achievement cut-off (accuracy lower than 36.4% in grade 2, 36.4% in grade 4, and 45.5% in grade 6). Three outliers with invalid data entry were removed.

The final nationally representative sample of normal readers included a total of 945 children, 307 in grade 2, 316 in grade 4, and 322 in grade 6.

Information regarding reading instruction methods was collected and grouped into three categories: phonetic (focus on the alphabetic code), global (learning whole words), and combined. One-way analyses of variance were performed to examine differences between groups based on the three categories, with respect to reading different orthographic structures. No significant differences were found.

Measures

The three reading measures (Shany et al., 2006) described below were employed. National norms are available for all tasks.

In each test, all items were read. Based on reading time for all the items, the words-per-minute measure was calculated using the following equation: number of items $\times$ 60 s/total reading time in seconds. Accuracy was measured in percentage of accurately read items out of all items read.

Letter-diacritic mark combinations

The test consists of 57 items that represent the various diacritic marks, those representing vowels and those representing consonants. Each diacritic mark appears several times. Percent of correct responses and items-per-minute are calculated. Alpha-Cronbach is .93 in grade 2, .91 in grade 4, and .92 in grade 6. To compare the performance between the diacritic marks, a factor analysis using the varimax with Kaiser Normalization rotation method was conducted. This analysis revealed seven categories of phonological identity. Five categories represent the five vowels (a, e, i, o, u), one category includes the diacritic mark schwa (representing no vowel/e), and one category includes letters with no dagesh (representing spirant letters, פ, כ, ב). The diacritic mark categories and the reliability of each category are presented in Table 1 (based on a table presented by Ravid, 2005).

Pointed pseudowords

The test consists of 33 pointed pseudowords from two categories. The first category includes 24 legal pseudowords, letter strings that represent Hebrew morpho-phonological structures, for example, *nirpag* (pseudoword), which corresponds to *nivhal* (real word meaning was scared). The second category includes nine illegal pseudowords, letter strings that represent phonological strings that do not correspond to Hebrew morpho-phonological structures, such as *tutsted* and *taasta*. Both word types appeared on a single list, beginning with the legal and ending with the illegal pseudowords. Accuracy, defined as the percent of correct responses, was calculated separately for legal and for illegal pseudowords, while rate, in items per minute, was calculated for all items together. Alpha-Cronbach is .91 in grade 2, .90 in grade 4, and .89 in grade 6.

Table 1 Diacritic mark categories and corresponding reliability scores

Category	Vowel/consonant	Diacritic sign	Diacritic name	No. of items	Cronbach's α
1	*i*	בִ	hiriq	4	.60
		בִי		5	
				(total 9)	
2	*a*	בָ	Qamats	4	.63
		בַ	pattah	3	
		אֲ	Hataf-pattah	2	
		אֳ	Hataf-qamats	1	
				(total 10)	
3	*e*	בֵ	Serey	2	.73
		בֶ	Segol	4	
		אֱ	Hataf-segol	1	
				(total 7)	
4	*o*	בֹ	Holam	3	.78
		בוֹ		5	
				(total 8)	
5	*u*	בֻ	Qubuts	5	.81
		בוּ	Shuruk	5	
				(total 10)	
6	*e/0*	בְ	Schwa	5	.67
7	Spirant consonants	ב, כ, פ	No dagesh	6	.76

Pointed words

This test involves reading single pointed words in isolation. All 38 words are nouns, which represent different levels of frequency, lengths, and morphological structures. Percent of correct responses and items per minute are calculated. Alpha-Cronbach is .90 in grade 2, .85 in grade 4, and .75 in grade 6.

Procedure

Data was collected towards the last third of the school year, between April and June. Tasks were administered individually by trained graduate students in the field of education. All tasks were administered in a single session, during which children were asked to read aloud, first the letter-diacritic mark combinations, then the pointed pseudowords, and finally the pointed words.

Results

Question 1: To what extent is knowledge of the pointed system retained in advanced stages of reading acquisition?

To examine this question, we compared the rate and accuracy measures for the different orthographic structures both between grade levels and within each grade level.

To analyze reading accuracy, a two-way ANOVA of 4 (type of orthographic structure: letter-diacritic marks combinations, legal pseudowords, illegal pseudo-words, real words) × 3 (grades: 2, 4, 6) with repeated measures for type of orthographic structure was performed. To analyze reading rate, a two-way ANOVA of 3 (type of orthographic structure: letter-diacritic marks combinations, pseudo-words, real words) × 3 (grades: 2, 4, 6) was conducted. Overall mean accuracy and rate[1] scores for the different measures are presented in percentages in Table 2. The main effect of type of orthographic structure was significant $F(6, 831) = 2{,}150.33$, $\eta^2 p = .72$, $p < .001$, indicating significant differences in mastering the pointed system among the different orthographic structures, across grades. In addition, the interaction between type of orthographic structure and grade was significant $F(12, 825) = 53.46$, $\eta^2 p = .11$, $p < .001$, implying that there is a difference in the way that reading accuracy and rate develop across grades in each task. Based on Bonferroni's post-hoc analyses, the nature of the interactions is presented separately for accuracy and for rate.

Table 2 Mean accuracy scores (% of correct responses) and rate scores (words-per-minute) of children in grades 2, 4, and 6 for the four pointed orthographic structures

Variable	Grade					
	Grade 2 ($n = 258$)		Grade 4 ($n = 290$)		Grade 6 ($n = 295$)	
	M	SD	*M*	SD	*M*	SD
Reading accuracy						
Letter-diacritic mark combinations (57 items)	81.7	12.8	76.5	14.2	80.3	13.2
Legal pesudowords (24 items)	75.6	15.9	74.2	14.6	78.8	13.7
Illegal pseudowords (9 items)	59.5	26.6	54.4	28.1	64.6	24.9
Real words (38 items)	83.3	13.5	89.1	9.10	92.7	5.9
Reading rate						
Letter-diacritic mark combinations (57 items)	45.9	14.9	50.9	16.0	58.1	20.4
Pseudowords (33 items)	18.3	8.3	21.7	7.6	26.9	13.4
Real words (38 items)	31.7	15.4	52.5	17.3	66.5	21.3

Letter-diacritic mark combinations, legal pesudowords, illegal pseudowords, and real words

[1] Since rate scores were not available for all the participants in the present sample, the analyses were conducted on 837 children.

Reading accuracy for different types of orthographic structures across and within grades

Comparison between grades Bonferroni's post-hoc analyses indicated different developmental patterns in mastering the pointed orthographic structures. Grade 4 children were less accurate in reading combinations of letters and diacritic marks in comparison to grade 2 and grade 6 children, who did not differ from each other. Grade 4 children did not differ from younger children in reading legal pseudowords and both groups were less accurate than grade 6 children. When reading illegal pseudowords, children in grade 4 were less accurate than grade 6 children but no significant differences were noted between grade 2 and the other grades. A different pattern was noted in reading accuracy for real words, where grade 2 children were less accurate than those in grade 4 and both groups were less accurate in comparison to grade 6.

Comparison within grades Post-hoc Bonferroni analyses indicated that within all grades, accuracy of reading illegal pseudowords was significantly lowest in comparison to the other orthographic structures. However, a different pattern of relationships between the remaining three types of orthographic structures was noted. In grade 2, reading accuracy of letter-diacritic marks combinations was similar to accuracy for real words and these two orthographic structure tasks yielded significantly higher accuracy than did legal pseudowords. In grades 4 and 6, children read words significantly better than they read the other structures, but no difference was noted between accuracy of reading letter-diacritic marks combinations and accuracy of reading legal pseudowords. The developmental patterns are presented in Fig. 1.

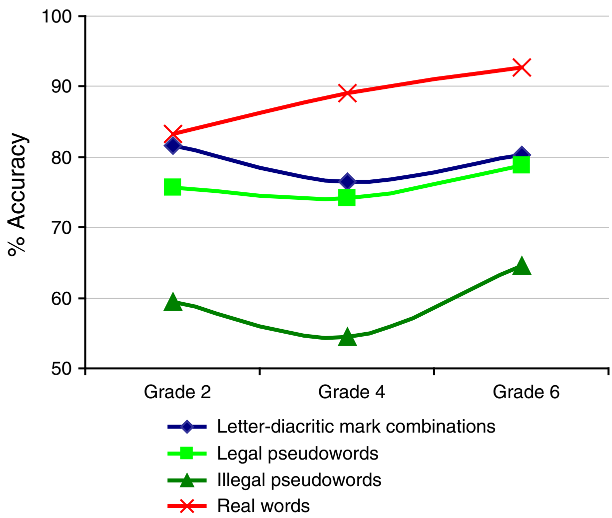

Fig. 1 Reading accuracy for different pointed orthographic structures across and within grade levels

Reading rate of different types of orthographic structures across and within grades

Comparison between grades Reading rate developed linearly from grade 2 through grade 4 to grade 6. Across all orthographic structure tasks, grade 2 children were significantly slower than grade 4 children, who were significantly slower than grade 6 children.

Comparison within grades Post-hoc Bonferroni analyses revealed that within each grade level, reading rate for pseudowords was significantly lower than reading rate for the two other tasks. However, the interaction showed that in grade 2, reading rate for real words was significantly slower than reading rate for letter-diacritic mark combinations, while in grade 4 these tasks did not differ, and in grade 6 reading rate for real words was higher than that for letter-diacritic mark combinations. The developmental patterns are presented in Fig. 2.

Question 2: Which diacritic marks are more stable, and which tend to be forgotten?

We tested whether there were differences in reading accuracy between the seven categories of diacritic marks, between and within grades (see Table 3). A two-way ANOVA of 3 (grades: 2, 4, 6) × 7 (letter-diacritic mark combinations) with repeated measures for categories was conducted. Overall means and standard deviations are presented in Table 3.

The overall analysis indicated a significant main effect of type of diacritic mark $F(6, 927) = 494.20$, $\eta^2 p = .35$, $p < .001$). Across grades, the order of the diacritic mark representations was as follows: $i > a$, *schwa* $> e > o$, $u >$ no dagesh (spirant letters), with all differences are at level of $p < .001$.

The analyses also revealed a significant interaction between diacritic mark category and grade level $F(12, 921) = 10.45$, $\eta^2 p = .022$, $p < .001$). Post-hoc Bonferroni

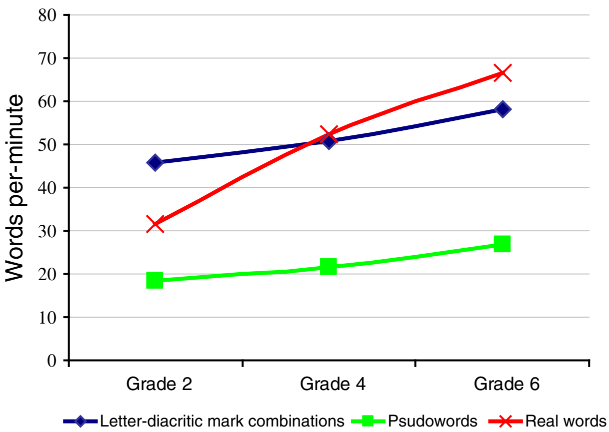

Fig. 2 Reading rate for different orthographic structures across and within grade levels

Table 3 Reading accuracy (% of correct responses) for letter-diacritic mark combinations

Letter-diacritic mark combination category	Grade							
	Grade 2 ($n = 299$)		Grade 4 ($n = 313$)		Grade 6 ($n = 321$)		Entire sample	
	M	SD	*M*	SD	*M*	SD	*M*	SD
Diacritic marks representing *i*	92.9	12.5	93.4	12.1	95.3	9.5	93.9	11.5
Diacritic marks representing *a*	86.5	13.5	81.8	17.2	85.2	14.9	84.5	15.4
Schwa	81.7	21.6	82.3	22.1	85.5	19.0	83.2	20.1
Diacritic marks representing *e*	80.2	23.3	73.6	25.1	80.4	21.7	78.0	23.6
Diacritic marks representing *o*	76.7	23.7	70.3	28.4	70.6	26.5	72.4	26.5
Diacritic marks representing *u*	73.7	26.7	69.5	25.9	75.5	26.1	72.9	26.3
Spirant letters—no dagesh	58.5	31.8	39.3	32.1	49.6	33.0	49.0	33.2

Mean performance scores and standard deviations

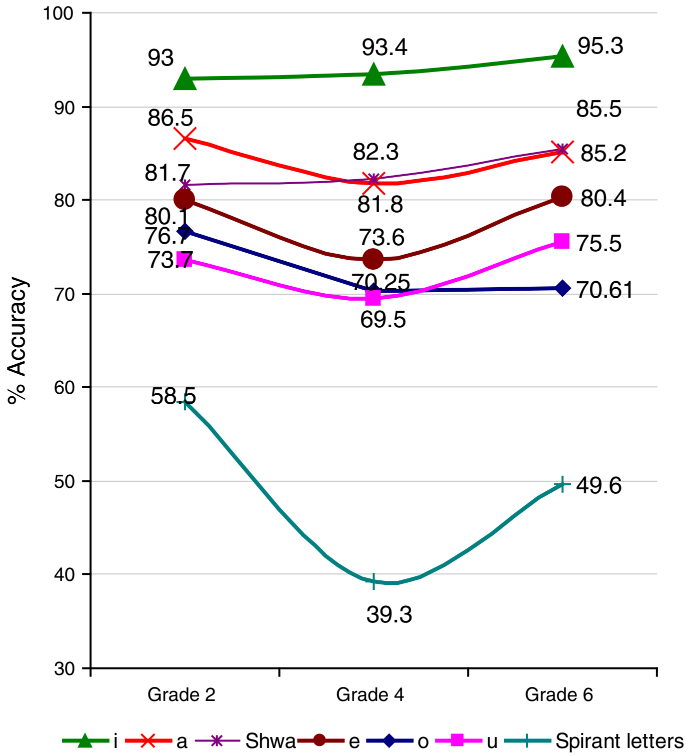

Fig. 3 Letter-diacritic mark combinations: Differences in accuracy (% of correct responses) by type of combination, between and within grades

analyses were conducted to reveal the nature of the interaction. Between grades, no differences occurred in reading accuracy of three categories of diacritic marks: *i*, *a*, and schwa. In the category of the diacritic mark *o*, grade 2 was better than grade 4

($p < .001$) and grade 6 ($p < .05$). In the category of the diacritic mark *e*, grade 2 and grade 6 exhibited higher accuracy as compared to grade 4 ($p < .001$). In the category of the diacritic mark *u*, grade 6 outperformed grade 4 ($p < .05$). In the category of the spirant letters, grade 2 outperformed grade 6 ($p < .001$) and grade 6 performed better than grade 4 ($p < .001$).

Within grades, in all three grade levels, the *i* category was better read than all other categories. The lowest accuracy level was noted for the spirant letters. In grade 2, the relation between categories was as follows: $a > u, o$, and *e*, schwa and $e > u$. In grade 4, *a* and schwa $> o, u$, and *e*. In grade 6, *a* and schwa $> o, u$. The developmental patterns are presented in Fig. 3.

Discussion

The current study adds two significant contributions to the literature on reading development. First, different developmental trends were found for rate and accuracy development, supporting an integration of both aspects in future models of reading. Second, the shift from reading a shallow orthography to a deep one was accompanied by non-linear trends in the pointed system, supporting the orthography-specific nature of reading development. Both of these issues will be addressed in the discussion.

Development of rate and accuracy of different orthographic structures

Most reading development studies have focused on the acquisition of reading accuracy, with less attention given to the role of rate and fluency development in reading (Share, 2008; Wolf & Katzir-Cohen, 2001). This study sheds new light on the importance of including both measures in our understanding of reading, especially as they appear to initiate different trajectories in a typically developing national sample of Hebrew-speaking children.

Our results indicate that rate develops linearly from grade two through grades four and six with respect to all three orthographic structures. However, steep development was demonstrated for word reading rate, as compared to moderate progress for the other two structures. Reading rate for letter-diacritic mark combinations was higher than for real words in grade two, equal to real words in grade four, and slower than real words in grade six.

These findings indicate that children in grade two achieve a high proficiency level in combination reading, but are still slow in word reading, since they read by phonological decoding. Children in grade four are able to identify whole words in a process termed *lexicalization* (Share, 1995). They therefore read faster, and this proficiency continues to improve in grade six. In contrast to real words, pseudowords (especially illegal pseudowords) are read using the phonological route and cannot be facilitated by lexical cues. Therefore, their rate was the slowest among the three constructions, at all ages. In this study we did not, however, control for word length of the legal and illegal pseudowords, and would recommend that future studies do so.

While a general linear trend was found for rate in this study, closer examination of accuracy development indicates that children become more efficient in producing oral naming responses to some pointed orthographic structures but not for all of them. In fact their accuracy in reading in the pointed system is mediated by their reading level in the non-pointed system.

Different developmental trends were found for reading real words, letter clusters with diacritic marks, and legal and illegal pseudowords. Because school children encounter the same or similar real words even after transferring to the non-pointed Hebrew system, it was not surprising that we found accuracy in reading real words develops linearly with grade as well. Our findings showed children in grade 2 to be at 83% proficiency levels, similar to previous findings regarding Hebrew readers (Share & Levin, 1999). This level develops to 89% and 92% in grades four and six, respectively.

The question is: what exactly does increased accuracy of pointed word reading reflect—increased knowledge of the point system, advancement in the process of lexicalization, or both? We can shed light on this question by looking at the surprising developmental patterns that emerged with respect to decoding of the other orthographic structures examined in this study, letter-diacritic mark combinations, legal pseudowords, and illegal pseudowords.

Readers in grade two achieved a high level of alphabetic knowledge regarding letters as well as diacritic marks. Thus, their accuracy levels were high for the letter-diacritic mark combinations and for the sequences of these combinations that make up words. Still, their knowledge level is not maximal, as evidenced by the 17% error rate they demonstrated when decoding both the combinations and the words. In grade four, improvement of pointed word reading continues alongside a decrease in the accuracy of reading the letter-diacritic mark combinations. This decrease is evidence that the improvement in word reading is not based on more effective use of phonological information provided by the point system but grounded, rather, in the process of lexicalization.

What then, becomes of the knowledge regarding the point system? The current findings are in line with those presented by Ravid (1996), which showed that children in grade one relied on diacritic marks, reading pointed sentences more accurately than children in grade four. These findings demonstrated the speed with which readers abandon elementary knowledge for new, more efficient knowledge. Ravid's study examined reading of sentences that included morphological, lexical, and syntactic information, such that reading them did not require reliance on diacritic marks. In decoding letter-diacritic mark combinations, on the other hand, the information provided is exclusively orthographic, such that the task requires the readers to pay full attention to the diacritic marks. In grade four, the 77% success rate shows that at a time when diacritic marks no longer constitute a source of information for the reader, this knowledge has not been entirely lost, but the decrease in accuracy with respect to grade two is evidence of diminished knowledge.

Accordingly, it would be expected that children in grade six, who have been reading non-pointed text for 2–3 years, would maintain the decrease in accuracy or show a further decline when decoding the letter-diacritic mark combinations. Thus, the finding that grade six readers showed an increase essentially equating their accuracy levels with those of grade two readers is surprising.

This nonlinear, U-shaped function of development offers the opportunity to shed light on the underlying process of reading development in Hebrew. While typically the assumption is that performance improves with age (Siegler, 2004), cognitive development is not always linear. Indeed, U-shaped development in cases such as stepping, verb generation in English, face recognition, and others (see Siegler, 2004 for review) are products of interaction between monotonic increases in specific capabilities (in this case rate, and reading the non-pointed version of Hebrew) and external circumstances in which behavior is produced (in this case the changing system that children are exposed to). From a Piagetian perspective, for children who are in the process of learning to read without the diacritic marks, being asked to make use of these marks in a testing situation may trigger disequilibrium. When further mapping these findings to reading development in other languages, many researchers studying the English orthography describe advancement in reading as a process accompanied throughout its duration by a dynamic balance between automaticity and attention; the more automatic one skill becomes, the more attention is available for another (Conners, 2009; LaBerge & Samuels, 1974). It is possible, then, that increased skill in non-pointed reading, acquired between grades four and six, enabled children in grade six to devote more attention and effort to the accurate decoding of the diacritic marks, components of a superfluous system. Thus, it may be that the process of release from the pointed system is in effect in grade four; these readers actively disregarded the marks and made do with the prominent clues, for example by relying on AHWY letters alone.

The non-linear development demonstrated in the decoding of letter-diacritic mark combinations is expected in the decoding of pseudowords as well. As with the combinations, accurate decoding of pseudowords relies on diacritic marks. Indeed, decoding of illegal pseudowords showed a non-linear developmental pattern similar to that shown for the letter-diacritic mark combinations, though the accuracy levels were much lower. Decoding illegal pseudowords is more complex than decoding letter-diacritic mark combinations due to increased cognitive load—pseudowords are constructed from assortments of letter-diacritic mark combinations, and to their bizarre nature—the illegal pseudowords were irregular both in terms of morphologic and phonotactic structure and in terms of orthographic structure, for example placing the combination כּ at the end of a word.

There is a debate in the literature regarding whether morphological processing has an independent contribution to reading, beyond phonological processing (Frost, 2006) and whether it changed as a function of age and the orthography. Evidence from Hebrew supports independent contribution of each process, more than in languages with morphologies that are not as rich (Frost & Grainger, 2000). In fact, a recent study of Hebrew-speaking children in grade five showed that the strongest predictor of speed and accuracy in reading pointed and non-pointed texts was morphological awareness, while phonological awareness did not contribute to either of them (Cohen-Mimran, 2009).

Findings from this study further support the growing reliance on morphological processing with age. While nonlinear development was found in illegal pseudowords, it was not demonstrated with respect to the decoding of legal pseudowords, which contained existing morphological structures. For these pseudowords, accuracy was higher as a whole, readers in grades two did not differ from readers in grade four, and grade six readers performed more accurately than the younger students. This trend can be attributed to the development of the morphological-pattern identification strategy, in which the reader decodes a word based on activation of its morphological form rather than through the phonological route (Bar-On, 2010). Morphological-pattern identification explains the ability of Hebrew readers to decode unfamiliar non-pointed words and supports the identification of each word as a whole. This morphological-pattern learning suggests that in the process of self-teaching, children not only learn specific orthographic patterns (Share, 1995), but also acquire general knowledge about morpho-orthographic units that may be transferable to reading novel words (Bar-On & Ravid, in press). The findings of Bar-On and Ravid (in press), who examined accurate identification of non-pointed legal pseudowords, show that the buds of morphological-pattern identification are present as early as the beginning of grade two and that during the course of the year this ability develops significantly. The reported accuracy differences between the two types of pseudowords among children in grade two supports these findings and indicates that even if the readers relied on diacritic marks for accurate identification, they were also supported by the morphological-pattern identification strategy and therefore achieved a greater level of accuracy. The finding that there was no advancement in the ability to identify legal pseudowords between children in grade two and those in grade four differs from the pattern reported in Bar-On and Ravid (in press). The explanation for this leans on (or possibly demonstrates) connectionist theories, which describe reading as a process of calculation based on various sources with weights that change over time (Harm & Seidenberg, 2004; Plaut et al., 1996). In the current study, accurate reading of the legal pointed pseudowords can rely on both the phonological information provided by diacritic marks and the morphological information provided by the word structure. Even if both groups made use of both information sources, it appears that in grade two the weight of the phonological information was greater than that of the morphological information, while in grade four there was a decline in the weight of the phonological information and an increase in that of the morphological information, such that in sum, both groups performed equally well.

The description above demonstrates the winding course of development of knowledge and use of the pointed system among Hebrew readers. Moreover, it illustrates a process in which a system, critical at the onset and later becoming obsolete, does not disappear, but rather is affected by skill level and automaticity. Investment of attention and resources in learning a new system (non-pointed) decreases the ability to allocate attention to the primary system (pointed). The more skilled and successful use of the new system becomes, the more attentional resources can be diverted to the primary system, even if it is not required.

And yet, in both grade two, when the pointed system is at the peak of its use and importance, and the grade six, when skilled reading makes it possible to allocate resources to the obsolete system, readers achieved only 83% accuracy in reading the pointed system. The question remains whether the 17% error rate was distributed equally among all the diacritic marks or resulted from specific marks more than others.

Thirteen diacritic marks represent the five vowels (*a, e, i, o, u*) and the *schwa* represents vowel absence. In addition to these is the dagesh, a point appearing within a letter, which differs from the other marks in that it provides information regarding consonants rather than vowels. Factor analysis showed that the various diacritic marks formed groups based on the phonological entity they represent, for example the four marks representing the vowel *a*, or the three letters, כ ,ב, and פ, that appear without a dagesh. In this manner, seven categories of diacritic marks were indicated: five groups, each including all the marks representing one of the five vowel sounds; one group representing the schwa mark; and the group of letters for which the spirant version is pronounced in absence of the dagesh mark. Among these diacritic mark categories, we examined whether there were differences in reading accuracy, and whether the pattern of differences was similar among the age groups.

The lowest accuracy level in all three grades was for letters for which the spirant version is pronounced in the absence of the dagesh. This finding has a number of explanations. First, the main function of diacritic marks is to provide information regarding vowels. It makes sense that within the context of a process that focuses attention on vowels, a mark that refers to consonants will be less prominent and that knowledge regarding this mark will be less stable. Furthermore, the dagesh can appear in 18 of the 22 alphabetic letters, although its appearance in most of these is redundant and does not provide phonological information. (For example, the letter ד is pronounced identically in the word דּג [*dag*, fish] and in the word חד [*xad*, sharp], despite including a dagesh in the first case and not in the second.) In three letters alone, the dagesh results in a phonetic distinction: the letters בּ, כּ, and פּ act as stop version consonants (*b*, *k*, *p*, respectively) when accompanied by the *dagesh*, and as spirant version consonants when unaccompanied by it (*v*, *x*, *f*, respectively). The fact that the presence or absence of the dagesh does not provide phonological information in most instances may lead the readers to ignore this mark, both in the general context of all letters and in the specific cases of ב, כ, and פ. In decoding each of these three letters as stop or spirant consonants, readers will make use of other factors. First, among these factors, the default for each of these letters is its stop version, as evidenced by the presence of this version at the start of each of their names: ***bet*** (ב), ***kaf*** (כ), and ***pey*** (פּ). Their pronunciation when they appear as part of a word is influenced by lexical and morpho-phonological factors, such that in certain contexts the stop version is used and in others the spirant version. In contrast, when they appear in isolation, as in the letter-diacritic mark combinations, we can expect them to be decoded based on their default versions as stop consonants. The second factor is related to the fact that these consonants almost always appear in their stop versions when found at the beginning of a word, and knowledge of this rule becomes intuitive among students as early as the second year of reading acquisition (Bar-On & Ravid, in press). As some of the letter-diacritic mark combinations that appeared in this study can potentially constitute Hebrew words (for example, those composed of two letters, the first representing a consonant and the second a vowel, as in בִי, pronounced *vi*), it is possible that this knowledge was utilized, resulting in the pronunciation of letters unaccompanied by a dagesh as stop consonants (בִי, *bi*, in myself).

While grade two readers were the most successful at decoding letters unaccompanied by the dagesh as spirant consonants, their success rate was low (60%). This finding is in accordance with those reported by Bar-On and Ravid (in press), who showed that even in the early stages of reading, in which formal knowledge about the point system still exists and the system is frequently used, morphological and lexical factors interfere and affect pronunciation, overpowering formally acquired knowledge. The 40% success rate among children in grade four is evidence that most children at this level ignored the phonological information, were influence mainly by the factors described above, and decoded letters without the dagesh as stop, rather than spirant, consonants. The 50% success rate demonstrated by grade six readers, which placed them between the second and fourth grades, shows that they also tended to ignore phonological information in this context.

Among the other six categories of diacritic mark, which include five groups representing each of the five vowels and one representing the schwa, the hierarchy shown in this study is similar to the previously reported hierarchy (Gur, 2004), which was explained based on the influences of various factors: frequency (as measured in pointed academic texts for the second and third grades by Gur), the transparency of the connection between the diacritic mark and the represented vowel (how many marks represent the same vowel; how many vowels are represented by the same mark), and the method by which the vowel is represented (diacritic mark alone or in combination with an AHWY letter).

The highest success rate achieved was for marks representing the vowel *i*. Among all the vowels, this one has the most transparent representation. It is represented using the hiriq mark, which can appear alone or in combination with the letter י (Y). For example מִ and מִי are both pronounced *mi*. The next two categories included the four marks representing the vowel *a* and the *schwa* mark, representing vowel absence. Gur (2004) found that the *qamats* mark (ָ), which represents the a sound, was the most frequent in the grade two and grade three texts, followed by the *hirik* (ִ), which represents the vowel *i*, and the *pattah* (ַ), which also represents *a*. Thus, two of the marks representing *a* were highly frequent. Gur's findings are also in accordance with the high distribution of the vowel *a* in auditory input received by children (Segall, Nir-Sagiv, Kishon-Rabin, & Ravid, 2009). Furthermore, in Hebrew reading instruction, *a* is the first vowel taught, and many beginning readers decode non-pointed words mistakenly using this vowel (Share & Blum, 2005). These factors explain the high success rates in decoding this vowel, although it appears that the transparency and the representation using the AHWY letter י present in the context of the vowel *i* were more prominent than the frequency factors, such that the vowel *a* was ranked second.

The *schwa mark*, representing vowel absence, was as successful as the *a* category. The transparence of this category is high, though it is not full. The schwa mark appears under the first or middle letters of a word, but not at the end of a word. In addition, while schwa represents vowel absence, it may also represent the vowel *e* when combined with some letters and in various word contexts. In this study, both methods of decoding—vowel absence and the vowel *e*—were accepted as correct answers, such that specifically with respect to the current research, the transparency of this mark was very high. The vowel *e*, which is represented by three exceedingly similar diacritic marks but is not represented by an AHWY letter, and has the lowest frequency of the aforementioned vowels, was associated with the lowest success rates. The *o* and *u* vowel categories were at the bottom of the hierarchy. Each of these is represented by two marks: first, *a* diacritic mark alone, where both that representing *o* and that representing *u* have the lowest frequency; and second, using the AHWY letter ו (W), with only the position of an identical diacritic mark distinguishing between the two vowels, such that *o* is represented by וֹ and *u* is represented by וּ. While the representation using the letter ו (W) constitutes strong support for precise identification, the duality of the letter increases the difficulty, and many children confuse the two vowels.

Connectionist learning theories describe how the efficacy of learning and the quality of representation within different systems are derived from the reciprocal relationships between a series of psycholinguistic factors: the frequency of the items, the categories, the patterns, the systems, and the frequency of the ties between them (Baayen, 2003; Saffran, 2003); transparency, that is, the clear connection between form and meaning or function; and regularity of representation, consistency, and resemblance of the items (Plunkett & Bandelow, 2006). These factors explain the hierarchy in knowledge of the Hebrew point system, which appeared in a similar manner in each of the three age groups. However, each of the categories showed a different developmental profile in each age group. With respect to the three diacritic mark categories that were associated with the highest accuracy rates (*a*, *i*, and schwa), there was no difference between age groups. The source of the U-shaped curve found in the decoding of letter-diacritic mark combinations were the four other categories: the vowel e and the letters unaccompanied by the dagesh, for which grade two readers performed better than grade four readers; the vowel *o*, for which grade two readers performed better than grade four and grade six readers; and the vowel *u*, for which grade six readers were more successful than grade four readers.

The non-linear developmental curve for the decoding of structures that are fully dependent on phonological information, as compared to the linear development with respect to the decoding of structures based on lexical and morphological factors, demonstrates the complexity of the reading acquisition process and the extent to which it has yet to be understood. This is particularly true in the case of a basic, initial system that is later abandoned in favor of a newer system, the decoding of which involves different reading strategies than those that were initially beneficial.

The current study has both theoretical and practical implications. Developmental models of reading in English (Chall, 1983; Ehri, 1998) describe the shift from correct reading to automatic and fluent, or efficient, reading, using phonological decoding of pseudowords as the accepted measure for evaluating reading accuracy. In Hebrew, phonological decoding requires the presence of diacritic marks. As such, correct reading is measured through decoding of pointed structures. The results of the current study, collected in a nationally representative sample of three grades that represent different stages in reading development, are evidence that the relevance of phonological decoding as a measure of the development of reading accuracy is dependent on orthography. In English, for example, accuracy in reading pseudowords develops linearly. In Hebrew, however, a non-linear pattern is displayed. Thus, while phonological decoding does indeed constitute a measure of reading ability in early reading stages, its relevance in this regard decreases, such that other measures are required for evaluating accuracy, in accordance with the unique character of the writing system. Further studies should examine additional means of evaluating reading accuracy in Hebrew, such as decoding of non-pointed pseudowords in morphological structures. In addition, it will be interesting to examine whether the developmental pattern revealed in average Hebrew readers will be similar among children diagnosed with reading disability.

A number of limitations of the current study should be noted. First, reading rate for the two types of pseudowords (legal and illegal) was measured in total. Second, pseudowords length was not controlled. In addition, in decoding letter-diacritic mark combinations, no comparison was made between the stop and spirant forms of specific letters. Future studies should also explore these issues.

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