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The effects of orthographic consistency on reading development: A within and between cross-linguistic study of fluency and accuracy among fourth grade English- and Hebrew-speaking children

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Cross-Linguistic Study of Accuracy and Fluency

The effects of orthographic consistency on reading development: A within and between cross-linguistic study of fluency and accuracy among fourth grade English- and Hebrew-speaking children

ABSTRACT

The different level of transparency of letter-sound mapping in various orthographies has been found to influence reading development across languages. The Hebrew orthography represents a special case of within language design with two versions of the script, a transparent (vowelized) and an opaque one (unvowelized). In this study we conducted a within and between comparison of word reading fluency and accuracy of English- and Hebrew-speaking children in fourth grade. In addition, the role of phonological awareness and vocabulary in predicting word reading in each language was examined. Findings suggest different trends for fluency and accuracy measures, with Hebrew-speaking children performing higher on word reading accuracy, and significantly lower on reading fluency. Phonological awareness was found to be a universal predictor of word reading in both languages. Vocabulary had an independent contribution to word reading only in English, indicating a unique role of verbal abilities to inconsistent orthographies.

Word count: 147

Key words: Fluency, Accuracy, Vocabulary, Phonological Awareness, Cross-linguistic
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1. Introduction

While advances have been made toward developing general theories of reading that look beyond the English language (see e.g., Frost, 1998, 2005; Perfetti, Liu, & Tan, 2005; Share, 2008; Ziegler & Goswami, 2005), it is becoming clear that fundamental differences exist between orthographies. Cross-linguistic work holds the promise of distinguishing the universal challenges of reading from the language specific ones. In order to further understand language specific challenges, cross-linguistic work needs to be developmental and extend beyond the early stages of reading, where the majority of work has focused up until now (Ziegler et al., 2010).

1.1. Orthographic consistency and reading processes

New cross-linguistic findings indicate that the rate of reading development and the cognitive mechanism involved in reading words may differ across writing systems with different levels of orthographic transparency. According to the Orthographic Depth Hypothesis (ODH; Katz & Frost, 1992), the more transparent the orthography, the more likely the reader is to rely on prelexical processes, whereby the phonological lexicon is accessed by assembling subword orthographic-to-phonological segments (Frost, 1994).

The majority of research on the effect of orthographic transparency has been based on cross-linguistic comparisons and on languages with two separate scripts such as Japanese and Chinese. However, some languages such as Hebrew and Arabic, have a single alphabet with two versions of script that offer a within language design to understand the different routes of reading in consistent and inconsistent writing systems (Share, 2008). In these scripts, the vowelized version is completely consistent (shallow), while the unvowelized version relies less on the phonological information thus is
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inconsistent (deep). These languages provide an interesting case of within language
design for examining the contribution of orthographic consistency to reading
development.

1.2. Orthographic consistency and reading development

Over the past decade, many studies have shown that orthographic consistency is a
key factor determining the rate of reading acquisition across languages (see Ziegler &
Goswami, 2005). Most of the cross-linguistic reading research has been based on
comparing literacy acquisition in English to that in Non-English languages with a focus
on early literacy in first and second grades. Probably the most wide ranging cross-
linguistic study of early stages of reading acquisition to date is the European COST
Action A8 comparison of first grade word and nonword reading in 14 different countries
(Seymour, Aro, & Arkins, 2003). This international collaboration found that the degree of
language transparency is related to the accuracy rates among beginning readers. Hence, in
highly transparent languages (Italian, Greek, and Spanish), children averaged at 87%
accuracy rates of high frequency words by the end of first grade, while accuracy rates in
less transparent languages (Danish, French) were lower (e.g., 80% in Danish and French,
and 34% in English).

Despite differences found in reading processes across languages, there are also
some universals. Ziegler et al. (2010) examined the reading performance in five different
European languages of varying degrees of transparency among second grade children.
They found that phonological awareness (PA) was the main factor associated with early
word reading performance although its impact was modulated by the transparency of the
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orthography, with higher impact for PA in less transparent orthographies (Chall, 1983; Ziegler et al., 2010).

In addition to the universal role of PA in word reading development, vocabulary has been hypothesized to influence not only comprehension (e.g., Gough & Tunner, 1986) but also word reading development (Nation & Snowling, 2004; Ouellette, 2006; Ricketts, Bishop, & Nation, 2007; Wise, Sevick, Morris, Lovett, & Wolf, 2007). According to this view, as more word forms are added to the lexicon, children become more and more sensitive to sublexical detail, thus benefiting growth in phoneme awareness (Walley, Metsala, & Garlock, 2003). In addition, it was shown that vocabulary was positively related to word reading beyond decoding (Ouellette, 2006), particularly irregular words in English (Ricketts et al., 2007). Given that irregular words rely less on grapheme-phoneme correspondences, children’s semantic knowledge might facilitate word recognition for these words. As studies of the role of vocabulary in early reading development have focused mainly on English (see Kim, 2010; Kim & Pallante, in press for exceptions), more research is needed to unravel the role of vocabulary for word reading in languages of varying orthographic consistency.

In summary, cross-linguistic studies demonstrate that compared to children learning to read a transparent orthography, children learning to read an opaque orthography such as English are at a disadvantage. However, there are a few gaps in the literature. First, the majority of the studies have focused on early reading acquisition with a focus on the role of PA in word level reading accuracy (Ziegler et al., 2010) in first and second grade, and studies comparing the role of PA and vocabulary to word reading in older children are scarce. Second, the main focus of the work on word reading has been
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on word reading accuracy with less attention given to word reading fluency. Finally, no investigations have directly compared reading in English to reading in orthographies with two versions of script. Comparison of reading acquisition in English vs. Hebrew provides such an opportunity because of the dual versions of script in which Hebrew-speaking children are required to become proficient.

In the present study, we compared the reading rate and accuracy profiles of fourth grade children in two languages, Hebrew and English, and examined the relationship of phonological awareness and vocabulary to timed and untimed reading in the two languages. Moreover, this was a three way comparison as Hebrew has two versions of the written script, one transparent with the diacritic marks, and one less transparent without them. A within and between comparison in these two languages will help illuminate the effects of orthographic consistency on later reading development in fourth grade.

1.3. The Hebrew and English orthographies

Among alphabetic orthographies, English has one of the most complex spelling systems due to the constant tradeoff between phonological and morphological spelling (Coulmas, 1999). In contrast to the inconsistent orthography of English, the vowelized version of Hebrew falls within the consistent orthography classification. Hebrew orthography also differs from English orthography in that each English grapheme represents a phoneme, while each Hebrew grapheme represents a syllable. In other words, Hebrew graphemes includes both consonant and vowel information which remains even after the diacritics are removed. In the Hebrew orthography, letters represent mostly consonants, while vowels are represented mostly by diacritic marks placed below, within, or above the letter. Four of the 22 consonant letters are given an additional function, to
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signify long vowels. Reading instruction in Hebrew starts with the vowelized version, and proficiency in decoding vowelized Hebrew is usually attained by the end of first grade (Share & Levin, 1999). By the end of fourth grade children are expected to be fluent readers of the unvowelized version of Hebrew. This version of Hebrew is considered a deep orthography, as the relation of orthography to phonology is more opaque with several possible sound correspondences applying to a string of consonants (Schiff, 2003).

Recent studies have indicated that the vowelized writing system in Hebrew plays an important role mainly in the first stages of the reading acquisition process (Frost, Katz, & Bentin, 1987; Shimron, 2006). As the proficiency of novice readers increases, and sufficient basic skills for decoding have been acquired, vowelization is no longer necessary for successful decoding. Based on these findings we would expect fourth graders in Israel to face a unique challenge. Just when they are expected to become fluent readers, they are deprived of the consistent grapheme to phoneme relationship as the script changes to the unvowelized version, which they have not learned to read in (Bar-On, 2010).

The transition to reading the unvowelized version in fourth grade has been shown to cause temporary interference with reading the system with the diacritic marks, which previously they have been proficient in, as children are learning that they can read without them (Shimron, 2006). In recent comparative research by Ravid and Schiff (2004, 2006) children in the fourth grade read vowelized words slower than second grade children. This shift to a less consistent system with missing phonological information
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may indeed influence fourth graders’ fluency and accuracy compared to children learning to read an orthography that does change over time.

1.4. The present study

The goal of the present study was to shed new light on whether reading in fourth grade varies with orthographic transparency. The novel aspect of our approach was that we used a within language (Hebrew with and without the diacritic marks) and between languages design (Hebrew vs. English). In addition, we examined differences both in accuracy and fluency. Three distinct hypotheses regarding the role of orthographic consistency in reading development are possible. The first represent a ‘strong’ view of the ODH, in which a transparent orthography will always be read more accurately and efficiently than an opaque one, thus vowelized Hebrew will be read better than the unvowelized Hebrew and English (Frost, 2005). The second hypothesis takes a developmental approach to ODH and states that orthographic consistency has more influence at the early stages of development and that by fourth grade English-speaking children should close the gap on reading with children learning to read in a transparent orthography as the vowelized Hebrew. Finally, the third hypothesis, the exposure vs. demand one, takes an adapted view of ODH, and states that there is an interaction between orthographic consistency and language specific process such that Hebrew-speaking children in the fourth grade, while having large exposure to print, are at a state of disequilibrium, leaving one script version and moving to another one, which may temporarily interfere with their reading speed of both versions of Hebrew script compared to their English speaking cohort of readers (Bar-On, 2010). In addition, we
examined the role of PA and vocabulary to fluency and accuracy in each script. Specific 
research questions that guided the present study were as follows:

1. Do fourth grade Hebrew-speaking children differ from English-speaking 
counterparts in their word reading accuracy and speed?
2. Is phonological awareness related to word reading in English and in the two 
scripts of Hebrew?
3. Is vocabulary knowledge related to word reading in English and in the two 
scripts of Hebrew?

2. Method

2.1. Participants

Eighty six average-achieving fourth grade children participated in the study: 
Forty four (24 girls) were Hebrew-speaking children, recruited from two schools in 
central Israel; and the other 42 children (19 girls) were English-speaking children, 
recruited from two schools in a north eastern community in the US. For each country, we 
selected a sample of children that was thought to be typical of the country’s grade four 
students in terms of socioeconomic makeup, ethnic composition, level of reading 
achievement, and overall cognitive performance. This was based on teachers’ referrals 
and also on local standardized reading measures in each language, which will be detailed 
below. The children were tested in the second half of the school year (between January 
and June). The average age was 9.4 years for English-speaking children and 9.1 for 
Hebrew-speaking children (range for both languages 9 -11 years). In both countries 
schools used a systematic code based approach to teaching reading in the early grades.

2.2. Measures
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It is difficult to compare literacy development across different orthographies because the stimuli must necessarily be different. In an effort to match assessment materials across languages, traditionally, there have been three main approaches. First, readers of different languages can be compared for their ability to read nonwords. This method has since been widely adopted because it provides an index of children's decoding abilities for novel material. Second, cross-linguistic translation equivalents can be compared for readability. A third approach has been to sample high-frequency words from children's school reading schemes (Ellis et al., 2004).

As Hebrew and English are languages that differ in their phonological, morphological and orthographical representations, tasks cannot be directly matched nor translated from one language to another. Thus, in this study, we used a combination of the first and second approaches. First, children were matched on their ability to read nonwords in an untimed condition (Woodcock, 1987) as well as on the definition task from the abbreviated Wechsler (1999). In Hebrew, reading nonwords must be given with diacritic marks in order to account for multiple pronunciation possibilities for any string of letters.

At the time of the study there were no local norms for any reading measures in Hebrew, and thus, these measures were developed by the first and second author for the present study. In addition, as there are no available data bases on word frequency, a team of four judges, who were two linguists and two literacy specialists, went over each task and rated it on three dimensions: 1) Does it conceptually match the English task? 2) Is it age appropriate for Hebrew-speaking fourth grade children? 3) Does it cover words from low to high frequency in the child’s language repertoire? An agreement of 90% or above
had to be reached on each question and for each item in order to be included in the final battery. In addition, in order to achieve similar conceptual demands, each task was developed to have the same number of items, and similar directions for administrations as the English Task. Each Hebrew reading measure had two versions (vowelized and unvowelized). The unvowelized condition included only unambiguous words. These tasks were constructed from the same pool of words and counterbalanced across conditions such that each word appeared for half the participants in the vowelized version and for half in the unvowelized version.

All tasks in each language were given in a counterbalanced order. In each country the measures were administered by trained graduate students in education in a quiet room over two sessions lasting an hour each. Analysis was conducted both on Z scores and on raw scores which yielded identical results. For ease of interpretation we report results in raw scores.

2.2.1. Vocabulary

Verbal IQ subtest of an abbreviated version of the WISC-III, the WASI (Wechsler, 1999), was used as a measure of verbal ability for both Hebrew- and English-speaking children in the study.

2.2.2. Phonological awareness

The Elision subtest of Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999) was used. In this task, children are required to say a word produced by the experimenter and then repeat the word after deleting either a syllable or a phoneme specified by the experimenter, with the correct response forming a real word. A similar task in Hebrew was developed (Cronbach’s alpha = .92).
2.2.3. Word level reading

Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999) was used as measures of word and nonword reading. TOWRE contains real words (104 words) and nonwords (63 words) of increasing level of difficulty arranged in four columns. The child was required to read aloud as many words as possible within 45 seconds. This is a timed word recognition test which measures word and nonword reading fluency and accuracy. In the analysis, separate scores were used for real word reading efficiency and for pseudoword reading efficiency in Hebrew and English, respectively. In Hebrew tasks, word reading efficiency was measured for both vowelized and unvowelized versions (Cronbach’s alpha = .95).

Word Identification of the Woodcock Reading Mastery-Revised (Woodcock, 1987) requires the participant to identify regular and irregular sight words with increasing difficulty within a 5-second limit per word. In the Hebrew tasks, children’s word recognition skills were measured in both vowelized and unvowelized forms. In the unvowelized version, only non-homophones were chosen (see Appendix 1; Cronbach’s alpha = .96).

Word Attack of the Woodcock Reading Mastery-Revised (Woodcock, 1987) assesses a child’s ability to apply grapheme-phoneme rules and word analysis skills to pronounce unfamiliar printed words (i.e., phonetically regular nonwords). As nonwords cannot be read without the diacritic marks, only the vowelized version was given in Hebrew (Cronbach’s alpha for Hebrew version = .95).

3. Results
3.1. Do fourth grade Hebrew-speaking children differ from English-speaking counterparts in their word reading accuracy and rate?

Table 1 displays children’s performance on various literacy measures. As expected, no differences were found on verbal IQ and nonword reading as measured by Word Attack (ps ≥ .48). In addition, no differences were found in phonological awareness (elision task) and in timed nonword reading on the TOWRE. Hebrew-speaking children significantly outperformed English-speaking children on both versions of the Hebrew Word Identification task (ts = -4.44 & -17.32, ps < .001). In contrast, English-speaking children outperformed Hebrew-speaking children in the timed word reading on the TOWRE (p < .001). Thus, Hebrew-speaking children were more accurate than the English counterparts, while English-speaking children were more efficient on a timed task.

When comparing Hebrew-speaking children’s performances on vowelized vs. unvowelized tasks, performance on timed word reading tasks was significantly better for an unvowelized version (ts = 2.48 & 3.14, ps ≤ .02, respectively) than for a vowelized version, while no differences were found between the two versions in the Word Identification task (t = -.21, p = .83).

3.2. Is phonological awareness related to word reading in English and in the two scripts of Hebrew?

Tables 2 and 3 show correlations between measures for English- and Hebrew-speaking children, respectively. Phonological awareness (i.e., Elision) was correlated with Word Identification in the three scripts, especially highly with Hebrew script.
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(Hebrew with vowels r = .64, without vowels, r = .65, English r = .39) as well as with timed word reading tasks (Hebrew with vowels r = .37, without vowels r = .54, English r = .31). Due to the small sample sizes, however, the differences in the correlation magnitudes were not statistically significant. Elision was also similarly correlated with Word Attack and TOWRE nonword reading speed (Word Attack in Hebrew r = .42, English r = .44).

<insert Tables 2 and 3 here>

Hierarchical regressions were conducted to determine the amount of variance contributed by phonological awareness to timed and untimed word reading after accounting for vocabulary knowledge for Hebrew- (Table 4) and English-speaking children (Tables 5). For Hebrew-speaking children, phonological awareness added unique variance to timed vowelized and unvowelized word reading task (i.e., TOWRE in Hebrew; 11 and 13 percent respectively) after controlling for vocabulary knowledge (Fs ≥ 5.30, ps ≤ .05). It added 29.9 and 21 percent of variance to vowelized and unvowelized word identification (ps < .001), respectively. For English-speaking children, phonological awareness did not add any significant variance after accounting for vocabulary knowledge in both timed and untimed word reading (see Table 5).

<insert Table 4>

3.3. Is vocabulary knowledge related to word reading accuracy and speed in English and in the two scripts of Hebrew?

<insert Tables 5 here>

As seen in Tables 2 and 3, Hebrew-speaking children’s vocabulary knowledge was significantly associated with the majority of the literacy measures except for timed...
word reading with unvowelized words and nonword reading speed (TOWRE) and accuracy (Word Identification). In fact, vocabulary knowledge was more strongly related to the unvowelized timed word reading task \( r = .45 \) than vowelized time word reading task \( r = .17 \); the 95% confidence interval for \( r = .45 \) did not include .17. For English-speaking children, vocabulary knowledge was significantly correlated with all literacy measures \( .32 \leq r_s \leq .44 \) except for Word Attack.

Regression results in Table 4 show that Hebrew-speaking children’s vocabulary knowledge was not related to timed (TOWRE in Hebrew) and untimed word reading (Word Identification; both vowelized and unvowelized) after controlling for phonological awareness. For English-speaking children (see Table 5) after accounting for phonological awareness, vocabulary knowledge was uniquely related to untimed word reading, but not timed word reading, adding approximately 12 percent of unique variance \( p < .05 \).

4. Discussion

This study adds to the existing literature in two central ways. First, it suggests that learning to read in different orthographies creates orthography-based differences in reading fluency and accuracy in the later stage of reading, not just in the initial stages in reading development. Children who learn to read in languages in which the depth of orthographic representation changes over time may encounter reading difficulties at the point of transition between orthographies compared to children learning to read an orthography that stays stable, even when it’s a deep orthography like English. Thus, not just the consistency of the orthography, but the consistent exposure to the exact same representation is important in reading acquisition. Our findings challenge two major aspects of current models of reading development which were mainly developed based on
findings from English-speaking children. First, they suggest that there is a need to include both fluency and accuracy in the study of reading. Moreover, there is no universal linear trend of progressing from accuracy to fluency (Chall, 1983; Ehri, 1992), particularly when during the process of learning to read, readers transition from a transparent to opaque script.

In terms of the relationship of different linguistic components to word reading, phonological awareness remains a significant universal contributor to word reading fluency and accuracy in English and both versions of Hebrew, even for fourth grade children. However, this is especially true for both versions of Hebrew in which phonological awareness explains a larger percent of the variance compared to its role in English word reading. An opposite trend is found for vocabulary, in which there was a language specific effect, as it explains larger percentage of the variance in English reading, and does not add any variance to vowelized Hebrew after controlling for phonological awareness.

4.1. Between languages comparisons of fluency and accuracy differences in pseudowords and word reading measures

This study is the first to compare the pseudoword and word reading of fourth grade English-speaking children to those of Hebrew-speaking children reading the two Hebrew scripts, on measures of both accuracy and fluency. One of the most interesting findings of this study is that English and Hebrew children did not differ on pseudoword reading measures which reflect pure phonological assembly that is not mediated by semantic knowledge (both timed and untimed). This shows that differences in decoding skills in deep and shallow orthographies may become neutralized by grade 4.
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These findings suggest that the first strong claim of ODH that a transparent orthography will always be read more accurately and efficiency than an opaque one was not supported in the between language design. In fact, the second developmental view of the ODH was supported, in the sense that early challenges that English-speaking children exhibit in decoding are not found in this study of fourth grade children (Seymour, Aro, & Arkins, 2003).

When examining word reading, the Hebrew-speaking children performed significantly higher than the English-speaking children on untimed word reading. On the other hand, English-speaking children outperformed the Hebrew-speaking counterparts on the TOWRE, a timed word reading task. This advantage that Hebrew speakers exhibit might be attributed to the fact that unlike English, Hebrew conveys some phonological information through morphological cues even when the diacritic marks are deleted (Bar-On, 2010; Frost, 2005). Thus, their solid orthographic foundation has not been debilitated in the transition from one version of the script to another. Indeed, Hebrew phonological recoding is easy to master for children and it is the sine qua non for successful reading acquisition (Share & Levin, 1999). In addition, this may be due to the fact that Hebrew-speaking children have been taught to read in a consistent orthography and thus may have had more practice in self-teaching (Share, 1995). However, the transition from reading a fully consistent vowelized version to reading a less consistent system causes them to be slower and less efficient than children who, despite reading an irregular orthography, are reading the same version of script for at least four years in school. Hence, in terms of the "self-teaching" hypothesis, in the fourth grade, a "self-teaching process" takes place again which is different than the one employed in lower
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levels with heavy reliance on grapheme-to-phoneme correspondence. Now word reading involves multiple processes to a greater extent in addition to grapheme-to-phoneme correspondence, such as morphological processing (Bar-On, 2010). Fourth grade readers still make use of the orthographic information they have gathered in reading vowelized words, but the reliance on vowelization itself for decoding new words decreases.

Another possibility that needs to be further explored is that educators in the US have for some time recognized the importance of reading fluency in schools (Kim, Petscher, Schatschneider, & Foorman, 2010; Wolf & Katzir, 2001). The Israeli school system is only beginning to address the importance of reading fluency (Breznitz, 2006). It would be interesting to compare the reading performance of more proficient Hebrew readers after they have been exposed to the unvowelized condition for three or more years.

The second hypothesis that orthographic consistency has more influence in the beginning stages of development and that by fourth grade English-speaking children should close the gap on word reading with children learning to read in a transparent Hebrew orthography (i.e., vowelized version) was only partially supported. Indeed there was not a clear picture with gaps in untimed word reading accuracy, and strengths in fluency of the English-speaking children, again stressing the need for future studies to look separately at fluency and accuracy in reading across orthographies (Share, 2008). Finally, the exposure vs. demand dependant ODH hypothesis was fully supported. According to this hypothesis, Hebrew-speaking children in fourth grade, despite having large exposure to vowelized version, will experience relative difficulties with it due to the educational demand to change script versions. When asked to perform with timing
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constraints, Hebrew speaking children, similar to adults (Shirmon, 2006), exhibited a speed-accuracy trade-off and on the timed TOWRE measures they performed more poorly on the vowelized timed word reading task than the unvowelized version.

4.2. Within language comparisons of accuracy and fluency in vowelized and unvowelized Hebrew

In this study we found that the performance on timed reading of real words was better without vowels than on words with vowels, but in the untimed word reading, there was no difference between the two scripts. These findings are in accordance with previous findings indicating that although fourth grade Hebrew-speaking children accurately decode both scripts, reading speed is inhibited in the presence of the diacritic marks (Bar-On, 2010). Studies of Hebrew-speaking adults with dyslexia show similar findings (Wiess, Bitan & Katzir, in prep). These findings could indicate that the children were more efficient when reading the script they were currently using (being out of practice when it came to decoding vowels from diacritics). Alternatively, it could signal that different mechanisms are involved in reading vowelized and unvowelized versions. As there were significant differences not only on the performance time between the two version of the script but also in correlation patterns of the two scripts with other measures, it seems consistent with the view that the two scripts require two different processes for word recognition: assembling words phonologically via conversion of letters into sounds (in the shallow, vowelized script) and using orthographic patterns to access whole-word phonology (in the deep, unvowelized script) (Frost, 2006). Thus, without time pressure, reading by phonological recoding and reading by directly mapping orthographic patterns onto semantics were similarly effective, but under time pressure, children were faster
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with unvowelized script because using larger units in reading is more efficient. This interpretation of the result would indicate that having been trained on a new version of Hebrew script, instead of regressing, the children actually showed a behavior consistent with that of more experienced readers. Overall, these findings support the third hypothesis indicating an interaction between the writing system and the course of reading development in a language.

4.3. The universal and orthography specific role of phonological awareness and vocabulary to word reading

Consistent with Zielger and his colleagues’ (2010) finding, PA was significantly related to word reading accuracy and rate in the three scripts. However, the relative contribution of PA was higher for the Hebrew-speaking fourth grade children. Researchers have argued that PA is a major predictor of reading development, especially in younger children reading deep orthographies such as English (Share, Jorm, Maclean, & Matthewes, 1984). However, for fourth grade English-speaking children, there may be a shift in reading strategy from pure assembly to whole word reading and/or reliance on larger units such as morphological/orthographic patterns, as when entered after vocabulary in the regression, for the English speaking children PA was no longer a significant predictor or word or nonword reading. In order to further understand the reading strategy employed by older readers, future studies should include morphological and orthographic measures as potential predictors of word reading.

The significant correlation between PA and reading vowelized Hebrew counters previous claims that PA plays a reduced role in transparent languages (Landerl
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&Wimmer, 2008; Mann & Wimmer, 2002). It may be that the Hebrew-speaking children
in the present study who are in a transient stage revert back to sounding out words, and
thus PA is crucial for them.

When controlling for PA, vocabulary was a significant predictor of word reading
only for English speakers in this study. Surprisingly it did not add independent variance
to Hebrew. Although vocabulary was not uniquely related to word reading in Hebrew
after accounting for phonological awareness, the bivariate correlations revealed that
vocabulary was correlated with both the vowelized and unvowelized untimed word
reading in Hebrew, yet in the timed condition, it was correlated only with the
unvowelized word reading. These results underscore the role of vocabulary in less
consistent orthographies (unvowelized words in Hebrew) especially those with greater
exposure over time (English), where at this later stage, the struggle with decoding is less
of a challenge for most readers. This finding is consistent with previous studies with
English-speaking children indicating that oral vocabulary has been linked to irregular
word reading in particular (Nation & Snowling, 2004; Ouellette, 2006; Ricketts
et al., 2007). An influence of semantics on irregular word reading in English is consistent
with computational models of reading that connect semantics to orthography
(Coltheart, 2005; Harm & Seidenberg, 2004) as well as the developmental theory that
acknowledges a role of semantics in orthographic learning and subsequent sight-word
reading (Share, 1995).

Although we did not differentiate between irregular and regular words in the
English version in the present study, all Hebrew words in the vowelized form were
regular and all words in the unvowelized form, while unambiguous, could be nonword homophones and thus be considered inconsistent in the sense that there is no one clear sound-to-symbol correspondence. Taken together, the findings may suggest that different reading strategies are employed by Hebrew and English fourth graders. For English speakers semantics seem to mediate word reading more than PA whereas for Hebrew speakers, while related to word reading, PA is still more central. In order to further understand the orthography-based difference, future studies should include measures of morphological processing. Morphology has been linked to word reading in Hebrew both at the word and at the sentence level tasks (Mimran-Cohen, 2006; Primor, Pierce, & Katzir, 2011). A persistent question for the Hebrew language is does morphological information aid word reading by providing phonological and/or semantic cues. Including phonological, semantic, and morphological measures as predictors of word reading could help shed light on this question.

5. Conclusion

Taken together, the findings from this study suggest that both consistency and transition of depth of orthography influence the reading fluency and accuracy of children learning to read in different orthographies. The Anglophone preoccupation with irregularity and the problems of reading accuracy may be responsible for the lack of progress on issues of speed and fluency in reading models such as the ODH (Share, 2008). Perhaps a modified version of the ODH will account better for the interaction between culture, language and the different process involved in reading development.
Universal effects were found indicating that PA was related both to the consistent and inconsistent version of Hebrew literacy measures as well as for English-speaking children. The role of vocabulary was found to vary by orthographic depth as well. It should be noted that this study was limited to a relatively small sample of children only at fourth grade. Future larger scale longitudinal studies hold the promise of shedding more light on the developmental trajectories of learning to read from early to later stages in different orthographies. Furthermore, additional measures such as morphological and syntactical measures will shed light on the role of these components in reading different languages.
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Table 1

Descriptive statistics for verbal IQ, Elision, and literacy skills for English- and Hebrew-speaking children (N = 42 & 44, respectively)

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<th>t-statistics</th>
</tr>
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<tr>
<td></td>
<td>Mean (SD)</td>
<td>Min-Max</td>
<td>Mean (SD)</td>
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<tr>
<td>Verbal IQ</td>
<td>11.09 (2.2)</td>
<td>8-18</td>
<td>10.93 (3.2)</td>
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<tr>
<td>Elision</td>
<td>14.09 (4.29)</td>
<td>6-20</td>
<td>12.48 (5.34)</td>
</tr>
<tr>
<td>TOWRE: real words</td>
<td>67.24 (7.86)</td>
<td>51-89</td>
<td>52.77 (12.17)</td>
</tr>
<tr>
<td>TOWRE: real words with Vowels</td>
<td>49.48 (12.64)</td>
<td>29-77</td>
<td></td>
</tr>
<tr>
<td>TOWRE: pseudowords</td>
<td>34.50 (9.73)</td>
<td>11-52</td>
<td>32.98 (10.03)</td>
</tr>
<tr>
<td>Word ID</td>
<td>70.79 (8.48)</td>
<td>50-88</td>
<td>84.05 (22.12)</td>
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<tr>
<td>Word ID with vowels</td>
<td>84.64 (18.79)</td>
<td>29-108</td>
<td></td>
</tr>
<tr>
<td>Word Attack</td>
<td>30.07 (5.88)</td>
<td>18-40</td>
<td>30.20 (10.61)</td>
</tr>
</tbody>
</table>

Note: Word ID = Word Identification

TOWRE = Test of Word Reading Efficiency
Cross-Linguistic Study of Accuracy and Fluency

Table 2
Correlations between measures for English-Speaking children (N = 42)

<table>
<thead>
<tr>
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<th>4</th>
<th>5</th>
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<tbody>
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<td>1. Verbal IQ</td>
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<td></td>
<td></td>
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<td>.31*</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>3. TOWRE: real words</td>
<td>.32*</td>
<td>.31*</td>
<td>---</td>
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<tr>
<td>4. TOWRE: pseudowords</td>
<td>.39*</td>
<td>.44**</td>
<td>.73***</td>
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<td></td>
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<tr>
<td>5. Word ID</td>
<td>.44**</td>
<td>.39*</td>
<td>.59***</td>
<td>.68***</td>
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</tr>
<tr>
<td>6. Word Attack</td>
<td>.19</td>
<td>.35*</td>
<td>.54***</td>
<td>.61***</td>
<td>.74***</td>
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Note: Word ID = Word Identification

TOWRE = Test of Word Reading Efficiency
Cross-Linguistic Study of Accuracy and Fluency

Table 3
Correlations between measures for Hebrew-speaking children (N = 44)

<table>
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<tr>
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<td></td>
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<tr>
<td>2. Elision</td>
<td>.52***</td>
<td>---</td>
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<td>.54***</td>
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<td>4. TOWRE: real words with vowels</td>
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<td>.37*</td>
<td>.75***</td>
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<td>5. TOWRE: pseudowords</td>
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<td>.42***</td>
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<td>.67***</td>
<td>.47***</td>
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<td>7. Word ID with vowels</td>
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<td>.64***</td>
<td>.49**</td>
<td>.51***</td>
<td>.50**</td>
<td>.60***</td>
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<td>8. Word Attack</td>
<td>.28~</td>
<td>.44**</td>
<td>.17</td>
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<td>.44**</td>
<td>.35*</td>
<td>.69***</td>
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Note: Word ID = Word Identification
TOWRE = Test of Word Reading Efficiency
Table 4
The results of the hierarchical regression models for Hebrew-speaking children timed word reading predicted by verbal ability, phonological awareness and reading. (N= 44)

<table>
<thead>
<tr>
<th>Step</th>
<th>Variables</th>
<th>R</th>
<th>(\Delta R^2)</th>
<th>(\Delta F)</th>
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</thead>
<tbody>
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<td>Outcome: TOWRE Vowelized</td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>Verbal Abilities</td>
<td>.17</td>
<td>.03</td>
<td>1.21</td>
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<tr>
<td>2</td>
<td>PA</td>
<td>.37</td>
<td>.14</td>
<td>5.30*</td>
</tr>
<tr>
<td>1</td>
<td>PA</td>
<td>.37</td>
<td>.14</td>
<td>6.75*</td>
</tr>
<tr>
<td>2</td>
<td>Verbal Abilities</td>
<td>.37</td>
<td>.01</td>
<td>.04</td>
</tr>
<tr>
<td>Outcome: TOWRE NOT Vowelized</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Verbal Abilities</td>
<td>.448</td>
<td>.201</td>
<td>10.538**</td>
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<tr>
<td>2</td>
<td>PA</td>
<td>.572</td>
<td>.126</td>
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<td>.536</td>
<td>.287</td>
<td>16.892***</td>
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<td>Verbal Abilities</td>
<td>.572</td>
<td>.040</td>
<td>2.47</td>
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<tr>
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<td>.342</td>
<td>.117</td>
<td>5.52*</td>
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<tr>
<td>2</td>
<td>PA</td>
<td>.644</td>
<td>.299</td>
<td>20.933***</td>
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<td>.415</td>
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<td>Outcome: Word Identification NOT Vowelized</td>
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<tr>
<td>1</td>
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<td>.252</td>
<td>14.38**</td>
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<tr>
<td>2</td>
<td>PA</td>
<td>.680</td>
<td>.210</td>
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<tr>
<td>1</td>
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<td>.652</td>
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<tr>
<td>2</td>
<td>Verbal Abilities</td>
<td>.680</td>
<td>.037</td>
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</table>

Note. PA = Phonological Awareness; Verbal abilities = Verbal IQ
*p < .05, ** p < .01, *** p < .001
Table 5
The results of the hierarchical regression models for English-speaking children timed word reading (TOWRE) and untimed word reading predicted by verbal ability and phonological awareness (N = 42)

<table>
<thead>
<tr>
<th>Step</th>
<th>Variables</th>
<th>R</th>
<th>ΔR²</th>
<th>ΔF</th>
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<td>.105</td>
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<td>2</td>
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<td>2.62</td>
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</table>

Outcome: Word Identification

<table>
<thead>
<tr>
<th>Step</th>
<th>Variables</th>
<th>R</th>
<th>ΔR²</th>
<th>ΔF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>.190</td>
<td>9.142**</td>
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<td>.151</td>
<td>7.108*</td>
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<tr>
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<td>Verbal Abilities</td>
<td>.511</td>
<td>.116</td>
<td>5.791*</td>
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</table>

Note. PA = Phonological Awareness; Verbal abilities = Verbal IQ; TOWRE = Test of Word Reading Efficiency

*p < .05, ** p < .01
Acknowledgements: This study was supported by a Spencer fellowship to the first author. We would also like to thank Noa Shoshan for her help with data collection and the teachers and students at the participating schools for their support of this project. We also wish to thank an anonymous reviewer for the helpful comments.