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Multiple dimensions of affix spelling complexity: analyzing the performance of children with dyslexia and typically developing controls

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Abstract

This study examined affix letter spelling among 6th grade Hebrew-speaking children with dyslexia compared with chronologically age-matched and reading level-matched controls. As different languages are characterized by multiple dimensions of affix spelling complexity, we specifically targeted the following unique dimensions relevant to Hebrew: (i) affix envelope transparency; (ii) affix letter prevalence; (iii) internal morpho-phonological competition; (iv) overtness of the phonological-orthographic link; and (v) phono-morpho-orthographic consistency. The research instrument was a spelling task of 244 words containing affix letters, covering all non-root morphological roles, both inflectional and derivational. Results show that for both frequent and infrequent words, 6th graders with dyslexia perform similarly to reading age-matched controls when spelling involves morphological competition or when the phonological morphological and orthographic link is inconsistent. In frequent words the similarity in performance between the groups extends to the overt phonology criterion as well. In addition, 6th graders with dyslexia were assisted by affix letter prevalence but not by demarcation of the affix envelope, compared with reading age-matched controls. Regarding these criteria, the discrepancy between regular and irregular affix spelling was different between dyslexic children and non-dyslexic controls. These findings indicate that morphological knowledge in dyslexia is not a unified system, and while some morpho-orthographic regularities are acquired more easily, other morpho-orthographic regularities are quite challenging.

Keywords Spelling · Affix · Dyslexia · Morphology · Word frequency

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Introduction

Learning to spell in any alphabetical writing system requires understanding how the written language represents the spoken language. Hebrew, like other languages with alphabetic writing systems, does not have a perfect one-to-one phoneme-to-letter relation, nor is it the only language to represent morphology in its orthographic patterns. Research shows that children with dyslexia can encounter major difficulties in building up these representations (Law et al., 2018; Snowling, 2000). Nevertheless, various studies have indicated that individuals with dyslexia can use morphological awareness knowledge to scaffold more effective spelling skills similar to spelling-age controls (Diamanti et al., 2014; Tsesmeli & Seymour, 2009), and that variation in morphological awareness may impact spelling ability (Tainturier & Rapp, 2001). The current study examined affix letter spelling among Hebrew-speaking children with dyslexia compared with chronologically age-matched and reading level-matched controls, providing a unique window into the way in which morpho-orthographic principles and word frequency influence dyslexic children's spelling performance.

Affix spelling provides important insights into the learning of statistical morpho-orthographic patterns from printed input, as well as into how phonological and morphological structures are represented in the mental lexicon (Protopapas et al., 2013). In a previous publication, Schiff et al. (2020) provided an analysis tool for the fine-grained investigation of affix spelling errors, outlining five morpho-orthographic categories: (i) affix envelope transparency—the extent to which the affix is demarcated from the root morpheme; (ii) affix letter prevalence—the occurrence of the affix letter in its morphological and orthographic roles; (iii) internal morpho-phonological competition—the existence of homophonous letters in similar affix roles; (iv) overtness of the phonological-orthographic link—the extent to which the orthographic segment represents a phonological unit; and (v) phono-morpho-orthographic consistency—the extent to which spelling patterns are perceived by spellers as a generalization. These five criteria of affix spelling constitute complexity metrics that pinpoint the loci of spelling challenge in homophonous Hebrew affixes. In what follows, we investigate the implication of these five categories for spelling ability differences in dyslexia, i.e., we examine the extent to which children with dyslexia are sensitive to these principles of affix spelling. Using a reading-level matched design, we compared the performance of 6th grade children with dyslexia to that of typically developing 2nd graders of the same reading-grade level, on the one hand; as well as to typically developing age-matched controls. The comparison to the reading-level matched controls makes it possible to understand whether the dyslexics' spelling difficulties stem from atypical or delayed development. Specifically, if children with dyslexia show a different pattern of affix spelling relative to reading-level matched controls, it is likely that they present atypical development. Alternatively, if children with dyslexia show similar affix spelling performance to the typically developing reading-level control group, then they might be viewed as having delayed development.

A statistical learning theoretical framework of spelling

Children learn to spell through repeated exposure to spelling regularities at multiple levels (Deacon et al., 2008). Thus, the number of times a word occurs in the language significantly impacts the quality of its lexical representation and ultimately its spelling acquisition. As lexicality and regularity have been found to play a powerful role in spelling development (Bourassa & Treiman, 2003; Gagl et al., 2015), experienced readers demonstrate higher spelling performance (Reichle & Perfetti, 2003; Tsesmeli & Kariotaki, 2020). This influence of whole-word lexical processing on spelling has been found in both opaque (e.g., Bosse et al., 2003; Martinet et al., 2004) and transparent orthographies (Angelelli et al., 2014).

The statistical learning approach to spelling development is supported by studies testifying to the substantial effect of grapheme-phoneme correspondence and graphotactic regularities on the acquisition of spelling (Deacon et al., 2008). This premise of spelling development assumes that children acquire letter co-occurrences, spelling patterns and regularities before they have formal command of word phonology. Studies have shown that the frequency with which children use particular strings of letters is related to the frequency with which the letters appear in written materials (Treiman, 2018; Treiman et al., 2018). This sub-lexical effect has been demonstrated in several European orthographies. For example, by providing entropy values for both grapheme-to-phoneme and phoneme-to-grapheme correspondences, Scheppert et al. (2017) were able to predict early spelling acquisition based on the uncertainty between phoneme-to-grapheme mappings and grapheme-to-phoneme mappings in languages belonging to three different typologies. While studies on the acquisition of spelling regularities in transparent orthographies are scarce, in English and French, single-letter positional frequency or graphotactic regularities have been found to promote spelling (e.g., Treiman 1993), or the recall of newly learned orthographic representations (e.g., Pacton et al., 2013). Taken together, the available research supports the claim that children implicitly pick up and produce spelling regularities (Deacon et al., 2008; Treiman & Kessler, 2014).

Children also need knowledge of morphological regularities to spell words correctly. Morphological awareness has been found to predict variance in word spelling even after controlling for the effect of phonological awareness (Nagy et al., 2006). Evidence shows that earlier in literacy development, spellers utilize word morphology in order to select the correct spelling (Deacon & Bryant, 2006a; Ravid, 2012). Thus, the same word ending (e.g., *smarter* vs. *corner*) is spelled better if perceived as a suffix preceded by a lexical base; and a letter string is better spelled when included in a morphologically complex rather than a simplex word (e.g., *turning* vs. *turnip*, Casalis et al., 2011; Deacon & Bryant, 2005a, 2005b, 2006b). Moreover, the presence of words in the same morphological family facilitates the spelling of the appropriate silent final letter. For example, Sénéchal (2000) showed that 2nd and 4th graders better spelled lexical bases ending with a silent letter that is pronounced in a morphologically related word than one that is not. This ability was significantly related to children's morphological awareness and vocabulary size.

Affix spelling in dyslexia

Developmental dyslexia is the most prevalent learning disorder (5–15% of school age children; American Psychiatric Association, 2013), characterized by stark and continuing impairments in reading accuracy and fluency and spelling, despite intact intelligence and proper teaching. Dyslexia typically involves difficulty with phonological and orthographic coding and processing (Berninger et al., 2015; Connelly & Dockrell, 2016; Silliman & Berninger, 2011), as well as continuing struggle in memorizing orthographic structures (Cassar et al., 2005; Silliman & Berninger, 2011). This impairment leads to a high frequency of spelling errors among children with dyslexia, often similar to those of younger, typically developing children (Bourassa et al., 2006; Bourassa & Treiman, 2003; Cassar et al., 2005).

Indeed, studies have reported impaired spelling in children with dyslexia compared to reading matched controls (Casalis, 2014; Plisson et al., 2013) or spelling matched controls (Cassar et al., 2005). Several studies adopted a theoretical framework of statistical learning when investigating spelling abilities in dyslexia (Marinelli et al., 2017, 2021). These studies support the notion that children with dyslexia, similar to typically developing children, are able to extract orthographic regularities from written input. Marinelli et al. (2017) found that children with dyslexia were able to tackle words with typical spelling, however, when challenged by words with unpredictable spelling, they relied on statistical learning processes to present a similar accuracy level as typically developing children. In a recent study on sensitivity to probabilistic cues in phoneme-grapheme mappings, Marinelli et al. (2021) showed that students with dyslexia had lower accuracy in spelling phonemes with irregular sound-spelling correspondence, especially in infrequent words.

Phonological deficits, responsible for impaired grapheme-to-phoneme mapping abilities, are considered the hallmark of dyslexia (Snowling, 2000). Therefore, most of the studies examining spelling in dyslexia have focused primarily on phonological errors (Caravolas & Volín, 2001; Landerl & Wimmer, 2000), which lead to poor utilization of the phonological procedure when spelling (Vellutino et al., 2004). However, various studies have indicated that similar to spelling-age controls, students with dyslexia can rely on morphological regularities for spelling morphologically complex words. This finding has been reported across different languages. For example, a study in English has previously shown that dyslexic students spell letter strings that are embedded in a morphologically complex word more accurately than strings that are not (Carlisle, 1987; Tsesmeli & Seymour, 2006, 2009). In Greek, students with dyslexia have been found to spell morphemic letter strings better than non-morphemic strings (Diamanti et al., 2014). More recently, Quémart & Casalis (2017) added to this body of research by showing that French-speaking dyslexics also activate morphological representations when spelling graphemes with no phonological counterpart.

The results of the studies that have investigated spelling in dyslexia leave gaps in our knowledge regarding the specific morpho-orthographic spelling cues to which dyslexic children are sensitive and that are needed for accurate affix spelling. Also, despite the wealth of evidence-based data regarding spelling in dyslexia in diverse languages, more information is necessary about the *types* of spelling errors made by

children with dyslexia, reflecting the types of morphological regularities that dyslexics have difficulty acquiring.

Against this background, we aimed to examine whether Hebrew-speaking elementary school students with dyslexia might rely on morphological abilities to overcome their spelling difficulties; and whether they display different patterns of affix spelling performance compared to typically developing age-matched and younger reading level-matched controls. These questions are especially prominent in a morphemically rich language such as Hebrew, where many semantic notions are expressed in word-internal morphemes, where large morphological systems organize the lexicon, and where multiple lexical categories are subject to morpho-phonological operations (Ravid, 2012, 2019).

Morphological spelling in Hebrew

Hebrew morphology provides strong support for overcoming spelling errors. In order to correctly spell a homophone (e.g., *t* that can be spelled by either ת or ט), being able to identify its morphological role as a root or affix morpheme is critical (Ravid, 2012). Studies have shown that Hebrew affixes are, in general, easier to spell and are learned earlier on than root letters (Ravid & Bar On, 2005). Homophonic root letters are extremely challenging, with a high type frequency and a low token frequency: The fact that all 22 letters participate in root spelling, the large number of Hebrew roots, the different levels of semantic relations between words in the same root family, and the frequent occurrence of homophonous letters in roots make root spelling a demanding task that requires multiple encounters with word-families sharing the same written root.

In contrast, homophonous affix spelling is generally less challenging, as affixes have lower type and higher token frequencies, coupled with higher morpho-orthographic transparency, than roots (Ravid, 2001). Only 11 of the 22 Hebrew alphabet letters serve as affix letters, and they stand for about 20 different morphological roles, both derivational and inflectional. Seven morpho-syntactic clitics (e.g., the definite article *ha-* and the coordinating conjunction *ve-*) are attached to the next Hebrew word in writing, thus also serving as prefixes in the Hebrew orthography (Ravid, 2012). Therefore, texts are much more saturated by affix than by root morphemes. Moreover, homophony, a major cause of spelling errors, is vastly reduced in affix spelling, as in most cases, only one of the two possible graphemes serves as an affix letter. For example, of the two letters ת ,ט which can spell *t*, ת alone has affix roles, while ט only serves as a root letter (Gillis & Ravid, 2006). The unambiguous demarcation of root and affix letters in the written word is thus of critical importance to Hebrew spelling acquisition (Ravid, 2012). Fortunately, these two morphological roles are reflected in the orthographic structure of the Hebrew word: root letters typically congregate in the center of the written word, whereas affix letters take peripheral positions in its outer envelope. For example, the pattern prefix and suffix of ***mi**klé**det*** 'keyboard' (in bold) are clearly demarcated in the written form מקלדת from the root קלד in the center.

However, not all Hebrew affixes are easy to identify and spell (Schiff & Levie, 2017). Recently (Schiff et al., 2020), analyzed and tested a set of affixes that constitute severe challenges to spelling due to different factors - the absence of morpho-orthographic transparency, differences in affix prevalence, affix competition in the same role, absence of direct linkage to phonology, and violation of a prevalent spelling generalization. These challenges to the morpho-orthographic principles guiding affix spelling in Hebrew were investigated in Hebrew-speaking school-going children and adolescents. Results showed that knowledge of morphological roles in orthography was the most significant factor that affected learning to spell affix letters in Hebrew. Importantly, a spelling hierarchy emerged in the interaction between grade level and the five morpho-orthographic principles.

The current study and research hypotheses

In the current investigation, we aimed to examine the extent to which Hebrew-speaking children with dyslexia are sensitive to morphological aspects of Hebrew affix spelling, as compared to this sensitivity in reading age- and age-matched controls; and whether this sensitivity interacts with word frequency. To this end, the current study examined the role of the five morpho-orthographic principles in affix letter spelling depicted in Schiff et al. (2020): (i) morpho-orthographic transparency; (ii) affix letter prevalence; (iii) morpho-phonological competition; (iv) overtness of the phonological-orthographic link; and (v) phono-morpho-orthographic consistency. These categories are presented and illustrated in detail below in the "Coding" section under "Method" section.

In general, the aim of the study presented here was to extend our knowledge regarding the types of morphological patterns that dyslexics find difficult to acquire. In particular, the current study explored the discrepancy between the regular and irregular values of the five spelling principles among the three study groups—6th graders with dyslexia (DD), chronologically age-matched controls (CA) and reading-level matched younger controls (RA). For each morpho-orthographic principle we measured the size of this discrepancy and whether it differed as a function of word frequency. A large discrepancy between the spelling performance on words with regular and irregular affix patterns would indicate that irregular affix spelling has yet to be fully acquired; whereas the absence of such a discrepancy would indicate that the morphological pattern has been fully acquired in the group.

We hypothesized that word frequency, on the one hand, and morpho-orthographic principles of homophonous affix spelling, on the other, constitute two separate factors that independently predict different spelling performance across groups. More specifically, based on Marinelli et al. (2017, 2021) and Quémart & Casalis (2017) who showed that dyslexic children showed a similar level of accuracy to typically developing children when challenged by words with unpredictable spelling, our specific hypotheses were as follows:

1. The discrepancy between regular and irregular affix spelling in the affix envelope transparency criterion would be similar in the DD and RA-control groups and higher among CA-controls.
2. The discrepancy between regular and irregular affix spelling in the affix letter prevalence criterion would be similar in the DD and RA-control groups and higher among CA-controls.
3. The discrepancy between regular and irregular affix spelling in the morpho-phonological competition criterion would be similar in the DD and RA-control groups and higher among CA-controls.
4. The discrepancy between regular and irregular affix spelling in the phonological orthographic link overtness criterion would be similar in the DD and RA-control groups and higher among CA-controls.
5. The discrepancy between regular and irregular affix spelling in the Phono-morpho-orthographic consistency criterion would be similar in the DD and RA-control groups and higher among CA-controls.

Method

Participants

The sample size was determined a priori by using G*power software. For the ANOVA with repeated measures (within-between interaction) analyses and the test parameters (effect size = 0.20, $\eta_p^2 = 0.04$, α error = 0.05 and power = 0.90), the total sample size required is 57 participants. In order to increase its power and sensitivity, the present study sample was comprised of 68 monolingual Hebrew-speaking students (29 boys and 39 girls), all from middle-high socio-economic status. The study group was comprised of 21 students with Developmental Dyslexia (DD) attending 6th grade, and the two control groups was comprised of 47 students with typical development (TD), randomly sampled from two grade levels—2nd and 6th grades. The twenty-three 2nd graders (Reading Age [RA]-controls) were matched to the DD students according to their performance on the reading accuracy level of unvoweled words (10 boys and 13 girls). The twenty-four 6th graders (Chronological Age [CA]-controls) were matched to the students with DD by chronological age (8 boys and 16 girls). The dyslexic children attended the same classes as the chronological age controls, while participating in remedial teaching and learning strategies lessons in small groups at the school. No significant difference was found in the gender distribution between the three groups $\chi^2(2) = 1.67$, $p = .434$.

In order to examine whether the verbal and the non-verbal intelligence of the participants was at a normal range, participants were given the vocabulary and matrix tests. Performance on both verbal and non-verbal intelligence was at a normal range between 7 and 13. One-way ANOVA analyses indicated that the three groups did not differ in performance on the verbal and the non-verbal intelligence tests, [$F(2,65) = 1.07$, $p = .349$, $\eta_p^2 = 0.03$ and $F(2,65) = 0.09$, $p = .914$, $\eta_p^2 = 0.00$, respectively]. Performance on the vocabulary and the matrix tests among students with DD did not differ from the performance of RA-controls and CA-controls.

In order to examine whether there were significant differences between the three groups in their performance on reading accuracy level of unvoweled words (Schiff & Kahta, 2008), a one-way ANOVA analysis was conducted. The three groups differed in reading accuracy, $F(2,65) = 58.95$, $p < .001$, $\eta_p^2 = 0.65$. Scheffé post-hoc analysis indicated that performance on the reading accuracy level of unvoweled words was significantly higher among CA-controls compared to RA-controls and the DD students. No significant difference was found between the performance of RA-controls and the DD students ($p = 336$). This result indicated that RA-controls were matched to the DD students on reading accuracy level of unvoweled words (see Table 1).

Materials

The research tools included three preliminary tests to assess participants' cognitive and reading abilities: a vocabulary test, a nonverbal intelligence test and a word accuracy reading test. The main tool for examining the research objectives was a spelling test (Schiff et al., 2020), comprising 244 words.

Nonverbal intelligence Nonverbal intelligence was assessed by the WASI Matrix Reasoning subtest (Wechsler, 1999). This task requires participants to choose an item from the bottom of the figure that would complete the pattern at the top. The maximum raw score is 60. Test reliability coefficient is 0.96.

Verbal intelligence Verbal intelligence was also assessed by the WISC-R (1976) vocabulary subtest. The Hebrew version of the WISC-R was standardized in the Hebrew population by Lieblich et al. (1976). This task required participants to define 23 words in ascending difficulty separately, while the answers were recorded. This test was done in order to rule out vocabulary effects on morphological skills.

The word reading accuracy test This test required participants to read aloud a list containing 112 unvoweled words (Schiff & Kahta, 2008). Scores ranged from 0 to 112, reflecting the number of correct answers given, with higher scores indicating higher reading accuracy. Reliability coefficients in retesting among all study groups are 0.96.

The affix letter spelling task This research instrument was a spelling-to-dictation task of 244 words, each containing one homophonous affix letter (Schiff et al., 2020). The affixes appearing in the target words represented five different affix categories or principles (four words per affix category), covering all of the function (non-root) morphological roles of Hebrew affix letters, both inflectional and derivational (Ravid, 2013). Table 2 provides examples of the affixes in the dictation task.

Half of the words (122) were of high frequency and half (122) were of low frequency. In order to validate the frequency classification of the Hebrew words (low frequency vs. high frequency), ten experts in the field of Hebrew language and linguistics evaluated an initial list of 248 words (Schiff et al., 2020). Each judge was required to assign a frequency level to each word on a scale of 1 (an infrequent Hebrew word) to 5 (a frequent Hebrew word). Words that were assigned a frequency level of 1 or 2 ($M = 1.51$, $SD = 0.34$) by all ten judges were defined as infrequent words, while words that were assigned a frequency level of 4 or 5 by all ten judges were defined as frequent words ($M = 4.75$, $SD = 0.35$). Due to disagreement among

Table 1 Descriptive statistics and F-values of students' demographics and performance on the preliminary tests by group

	DD (1) $n = 22$		RA (2) $n = 23$		CA (3) $n = 24$		F	P	η_p^2	*Scheffe*
	Mean	SD	Mean	SD	Mean	SD				
Demographic characteristics										
Gender (Boys/Girls)	11/10		10/13		8/16		$\chi^2(2) = 1.67$, $p = .434$			
Age	11.29	0.41	7.13	0.22	11.29	0.39	1089.33***	.001	.97	1=3 > 2
Verbal intelligence										
Vocabulary	10.14	0.79	10.04	0.93	10.42	0.97	1.07	.349	.03	–
Non-verbal intelligence										
Matrix	10.67	1.20	10.74	1.29	10.58	1.28	.09	.914	.00	–
Reading accuracy										
Non-voweled words	72.38	12.61	76.39	7.34	98.83	5.93	58.95***	.001	.65	3 > 1=2

***$p < .001$

Table 2 Examples of categories tested in the Affix Spelling Test

Affix	Hebrew spelling	Role	Example
ve-	ו	Coordinating conjunction	***ve****-az* 'and-then' ואז
t-	ת	Future tense/person prefix	***t****edaber* 'you-will-talk' תדבר
-t	ת	Nominal pattern suffix	*kapi****t*** 'teaspoon' כפית
-xa	ך	2nd person masculine possessive suffix	*bey****xa*** 'house-your' ביתך

the judges with regards to their frequency in the language, this stage resulted in the removal of four words from the final data collection tool administered to the study participants (See Appendices 1 and 2 for the final word lists and the frequencies). The internal consistency of Cronbach's Alpha of all items in the affix letter spelling test ($\alpha = 0.98$) as well as in each of the five categories ($\alpha = 0.70$–0.96), was high.

Procedure

The dictation task was administered individually, preceded by three examples. Each target word was presented orally within a short sentence to verify comprehension and avoid misunderstandings. Words were presented in a random order. The experimenter read the sentences one at a time and participants were instructed to write only the target word, which was repeated at the beginning and at the end of each sentence (Gillis & Ravid, 2006). For example: *mishkéfet*, *yesh la-yéledmishkéfet*; *tix-tevumishkéfet* 'goggles, the boy has goggles; please write: goggles'. To confirm that the participants had correctly perceived the target words, the experimenter asked them to say out loud each word before writing it down. No performance feedback was volunteered for the written response. Pauses and spontaneous corrections were allowed when requested.

Coding

Two main variables were considered in the coding process of the affix spelling task: word frequency and the morpho-orthographic principles of affix spelling. Affix coding was based on Ravid's work on the role of Hebrew morphology in spelling and lexical organization (Gillis & Ravid, 2006; Ravid, 2001, 2012, 2019). For the purposes of the current study, we used the specific morpho-orthographic classification recently introduced in Schiff et al. (2020) regarding affix spelling across the school years in typically developing populations. Five morpho-orthographic principles of homophonous affix spelling were used, each representing a different measure of affix complexity. Thus, each affix on the test was assigned binary values regarding each of the five principles, as explained below and illustrated in Table 3. Reliabilities of each category are available in Appendix 3.

Affix envelope transparency This principle refers to the extent to which it is possible to demarcate the affixal periphery from the central root morpheme. The binary

Table 3 Examples of the five morpho-orthographic principles

Principle	Regular example	Irregular example
1. Affix envelope transparency	***hit***kadem הִתְקַדֵּם 'advance'	***hi****s****t***ader הִסְתַּדֵּר 'arrange,Int'
2. Affix letter prevalence	***t***edaber 'you-will-talk' תְּדַבֵּר	beyt***xa*** 'house-your' בֵּיתְךָ
3. Internal morphological competition	***y***esader 'will arrange' יְסַדֵּר	***y***itnagev 'will-dry,Rfl' יִתְנַגֵּב
4. Overt phonological-orthographic link	ax***i***v 'brother-his' אָחִיו	ex***a***v 'brothers-his' אֶחָיו
5. Orthographic consistency	sagr***a*** 'she closed' סָגְרָה	sagart***a*** 'you, Masc closed' סָגַרְתָּ

Affixes are bolded and underlined

value for this criterion was either clearly demarcated (regular) or opaque (irregular), with performance predicted to increase for the transparent or regular value. A clearly demarcated affixal periphery is easier to identify and therefore we expected clearly demarcated envelopes to be spelled more correctly. Table 3 (Principle 1) shows that in ***hit***kadem הִתְקַדֵּם 'advance', the affix is regular in a transparently structured word, since it is easy to demarcate the affix letters ת, ה (together signifying the pattern prefix) at the beginning of the word from the root morpheme קדמ following this prefix. However, the same prefix in ***hi****s****t***ader הִסְתַּדֵּר 'arrange,Int' is irregular, that is, cannot be easily demarcated from the root, given that the first root letter ס intertwines with the prefix letter ת.

Affix letter prevalence. This principle refers to the frequency of the letter in its morphological and orthographic roles, i.e., the extent to which the affix letter serves a number of morphological roles (Ravid, 2013). The binary value for this criterion was either prevalent (regular) or non-prevalent (irregular). We predicted better spelling performance for highly prevalent homophonous letters compared to infrequent affix letters. Thus, a letter with multiple affix roles would have more occurrences in the language, which would strengthen not only the role of the letter as affix but also the environments where it is likely to appear (Ambridge et al., 2015). For example, ת, as in the regular example ***t***edaber 'you-will-talk' תְּדַבֵּר in Table 3 (Principle 2), serves as both a prefix and a suffix, fulfilling 11 different inflectional an derivational roles (Ravid, 2019). The irregular, non-prevalent suffix in beyt***xa*** 'house-your' בֵּיתְךָ illustrates the letter כ that has only two inflectional affix roles. Moreover, these affix roles are obscured by the fact that כ signifies both the stop *k* and the spirant *x*, and is often phonologically unstable, as delineated by Ravid (2001, 2012, 2019). Additional assessment for affix prevalence was performed by four language experts, who labelled the category size for each affix letter in each word on a scale from 1 (low frequency of the letter in its morphological and orthographic roles) to 5 (high frequency of the letter in its morphological and orthographic roles). The category size for prevalent affix letters ($M = 1.15$, $SD = 0.19$) was significantly higher ($p < .001$) than the category size for non-prevalent affix letters ($M = 4.76$, $SD = 0.25$). The Intraclass Correlation Coefficient of the four language experts, who labelled the

category size was high (ICC = 0.96) and the internal consistency of Cronbach's alpha was high (0.98).

Internal morpho-phonological competition This principle refers to the existence of homophonous letters in similar affix roles. The identification of a letter as having an affix role is a necessary, but not a sufficient condition for correct affix spelling even in clearly demarcated environments. The sufficient condition is the absence of competitors in the *same* affix role (the regular case). This condition becomes necessary in the spelling of ה *h* and י *y*, which both serve as tense (past and future tense respectively) prefixes in specific verb morphology environments. Table 3 (Principle 3) has ***y****esader* 'will arrange' יסדר as the regular example, where the third person future tense marker does not compete with any affix in a similar role. However, past tense 3rd person singular ***h****it****n****agev* 'dried oneself' התנגב and future tense ***y****it****n****agev* 'will dry oneself' יתנגב (the irregular example) differ only in the first letter of the prefix, and are very similar phonologically. The binary value for this criterion was either the presence (irregular case) or absence (regular case) of internal affix competitors. We predicted that in the presence of competition *within the affix category*, spellers would encounter greater difficulty differentiating between the two homophones, resulting in lower spelling accuracy.

Overt phonological-orthographic linkage This principle refers to the extent to which the orthographic segment represents a phonological unit. The binary value for this criterion was either overt (regular) or covert (irregular) phonology. In Hebrew spelling, phonological information is most often directly linked to the orthography, as in the regular example of Principle 4 (Table 3) *ax****i****v* 'brother-his' אחִיו, where י represents the vowel *i*. However, there are cases of *covert* phonology in which a letter does not represent a phonological segment, as in the irregular example *ex****a****v* 'brothers-his' אחיו. In this case, the possessive suffix *-av* 'his' is spelled with י *y* which is not directly linked to a phonological segment. We anticipated higher spelling performance in the overt phonology than in the covert phonology as the latter increases task complexity, especially in younger spellers.

Phono-morpho-orthographic consistency This principle refers to the degree of consistency in spelling patterns that spellers can adhere to as a generalization. One such spelling pattern is the prevalent link between a final feminine *-a* spelled by ה, as in the regular example for Principle 5 (Table 3) *sagr****a*** 'she closed' סגרה. This link indicates the representation of final vowels by vowel letters (Ravid, 2012). The generalization that learners acquire from these prevalent spelling regularities is that open syllables at the end of a word should be marked by a vowel letter, especially ה. When this generalization is apparently violated, as in *sagárt****a*** 'you, Masc closed' סגרת (the irregular case) it is very difficult to inhibit the generalization of adding the final closing vowel letter. The binary value for this criterion was either conforming to or violating phono-morpho-orthographic consistency. We predicted higher affix spelling performance in words in which the phono-morpho-orthographic consistency is not violated (the regular case) compared with words in which the phono-morpho-orthographic consistency is violated (the irregular case).

Results

Homophonous affix letters were each assigned five binary values corresponding to the five morphological principles as described above. Before examining the study questions and hypotheses, we conducted Shapiro-Wilk tests in order to examine whether the spelling scores were normally distributed for each of the frequency values of each word (infrequent words, frequent words), group and for each of the five principles. As some performance scores deviated significantly from normal distribution, we examined the study questions and hypotheses by conducting both parametric and non-parametric tests. The non-parametric analyses were Wilcoxon, Kruskal–Wallis, and Mann–Whitney tests. Wilcoxon tests were conducted to examine the differences in the performance scores between the two frequency values and the two regularity levels (regular, irregular) in each group. Kruskal–Wallis tests were conducted to examine group differences in each frequency value and in each regularity level. Mann–Whitney tests were conducted in order to examine which of the three groups had significant differences. The findings and the significance level of the non-parametric analyses matched the findings of the parametric analyses. Therefore, we presented the findings of the mixed ANOVA's analyses.

The discrepancy between the two-regularity levels of each measure represented the extent to which each regularity level exhibited higher performance scores on the homophonous affix spelling task. In this section, a two-way (3×2) mixed ANOVA analyses were conducted, with group (DD, RA-controls, CA-controls) as the between-subject factor, and regularity level (regular, irregular) as the within-subject factor, for each word frequency (infrequent words, frequent words) and each of the five morpho-orthographic principles of homophonous affix spelling (transparency of the affix envelope, affix letter prevalence, morpho-phonological competition, overtness of the phonological-orthographic, phono-morpho-orthographic consistency). In sum, 10 (3×2) mixed ANOVA were conducted. Since multiple hypotheses were tested among a small sample size, the chance of observing a rare event and making type I errors increases.

In order to decrease this risk for multiple comparisons, in cases where the interactions were significant, we restricted the α error and considered the results to be significant only at $\alpha < 0.001$. This restricted limitation of the alpha level is even more conservative than of the Bonferroni correction ($\alpha = 0.05/10 = 0.005$), which is considered to be a conservative method that increases chances of failure to reject a false null hypothesis, compared to other methods (Miller, 1966). In cases where the interactions were significant only at $\alpha < 0.05$ or $\alpha < 0.01$, the results were considered as marginally significant and were regarded with caution. In cases were the interaction between group and regularity level was significant, the differences in the success scores on spelling homophonous affix letters between two groups were further examined using a two-way (2×2) mixed ANOVA. These analyses aimed to examine, for each word frequency and morpho-orthographic principle, which of the groups exhibited a significantly higher degree of the discrepancy between the two-regularity levels. Finally, we examined

the source of the interaction by comparing between the two-regularity levels in each group, using paired samples t-test analyses and calculating Cohen's d effect size using the equation of effect size for paired samples.

Before the examination of the discrepancy between spelling performance of frequent and infrequent words with regular and irregular affix spelling in the three study groups, we examined whether the three groups differed on the proportion of correct items on the spelling test. One-way ANOVA indicated significant difference between the three groups on the proportion of correct items on the spelling test, $F(2,65)=65.74$, $p<.001$, $\eta_p^2 = 0.67$. The performance of the DD students ($M=59.09$, $SD=12.17$) was significantly lower than the performance of the RA-controls ($M=67.06$, $SD=11.62$, $p=.041$) and CA-controls ($M=92.20$, $SD=6.05$, $p<.001$).

Discrepancy between spelling performance of frequent words with regular and irregular affixes

Table 4 presents the results of the spelling performance of frequent words with regular and irregular affix spellings on the three study groups of the study.

The results of the two-way (3×2) mixed ANOVA with Group (DD, RA-controls, CA-controls) as the between-subject factor and the Regularity level (Regular, Irregular) as the within subject factor, indicated significant main effects of Group for the five morpho-orthographic principles, as follows: transparency of the affix envelope, $F(2,65)=63.45$, $p<.001$, $\eta_p^2 = 0.66$, affix letter prevalence, $F(2,65)=59.30$, $p<.001$, $\eta_p^2 = 0.65$, morpho-phonological competition, $F(2,65)=60.78$, $p<.001$, $\eta_p^2 = 0.65$, overtness of the phonological-orthographic, $F(2,65)=69.79$, $p<.001$, $\eta_p^2 = 0.68$ and phono-morpho-orthographic consistency, $F(2,65)=73.70$, $p<.001$, $\eta_p^2 = 0.69$. Scheffé post-hoc analyses indicated that the scores of the children in the DD group were significantly lower than the RA-controls and the CA-controls ($p<.001$) in all five morpho-orthographic principles. Furthermore, the scores of the RA-controls were significantly lower than the scores of the CA-controls ($p<.001$).

In addition, the results of the two-way (3×2) mixed ANOVA indicated significant main effects of Regularity level for the five morpho-orthographic principles, as follows: transparency of the affix envelope, $F(1,65)=162.76$, $p<.001$, $\eta_p^2 = 0.72$, affix letter prevalence, $F(1,65)=407.08$, $p<.001$, $\eta_p^2 = 0.86$, morpho-phonological competition, $F(1,65)=230.82$, $p<.001$, $\eta_p^2 = 0.78$, overtness of the phonological-orthographic, $F(1,65)=93.21$, $p<.001$, $\eta_p^2 = 0.59$ and phono-morpho-orthographic consistency, $F(1,65)=82.79$, $p<.001$, $\eta_p^2 = 0.56$. The results indicated higher spelling scores when the affix letter was regular compared to an irregular morpho-orthographic form.

Finally, the two-way interactions of Group and Regularity level were significant for the five morpho-orthographic principles, as follows: transparency of the affix envelope, $F(2,65)=29.78$, $p<.001$, $\eta_p^2 = 0.48$, affix letter prevalence, $F(2,65)=62.91$, $p<.001$, $\eta_p^2 = 0.66$, morpho-phonological competition, $F(2,65)=37.57$, $p<.001$, $\eta_p^2 = 0.54$, overtness of the phonological-orthographic, $F(2,65)=9.63$, $p<.001$, $\eta_p^2 = 0.23$ and phono-morpho-orthographic consistency,

Table 4 Descriptive statistics, effect sizes and F-values of the discrepancy between spelling performance in frequent words with regular and irregular morpho-orthographic principles

Morpho-orthographic principles	Group	Regular		Irregular		*t*	Cohen's d	*F-values (Group*Regularity)*		
		Mean (%)	SD	Mean (%)	SD			DD & RA	DD & CA	RA & CA
Transparency of the affix envelope	DD	62.76	14.67	53.51	10.64	3.93***	0.86	45.92***	.23	41.18***
	RA-controls	83.53	10.56	51.14	17.30	13.19***	2.75			
	CA-controls	97.75	2.76	86.90	11.52	4.73***	0.96			
Affix letter prevalence	DD	87.07	9.03	43.61	15.66	19.33***	4.22	6.26*	201.34***	58.96***
	RA-controls	91.01	8.59	57.55	17.56	10.39***	2.17			
	CA-controls	98.73	1.50	91.84	6.80	4.94***	1.01			
Morpho-phonological competition	DD	72.95	13.31	51.75	14.27	11.64***	2.54	2.38	71.06***	62.99***
	RA-controls	90.35	7.96	64.08	15.98	9.90***	2.06			
	CA-controls	96.94	3.21	93.05	5.92	3.62***	0.74			
Overtness of the phonological-orthographic link	DD	57.90	11.46	38.57	23.71	4.88***	1.06	.82	9.65**	25.31***
	RA-controls	73.99	12.25	50.19	20.86	7.89***	1.65			
	CA-controls	96.37	3.80	89.94	9.04	3.67***	0.75			
Phono-morpho-orthographic consistency	DD	65.24	11.13	41.33	21.53	7.13***	1.55	.63	47.01***	30.14***
	RA-controls	81.13	10.22	61.04	20.22	5.89***	1.23			
	CA-controls	96.15	3.14	95.86	6.24	.22	0.04			

*$p < .05$, **$p < .01$, ***$p < .001$

$F(2,65) = 20.78$, $p < .001$, $\eta_p^2 = 0.39$. As mentioned above, we further examined the differences in the success scores on spelling homophonous affix letters between two groups using two-way (2 × 2) mixed ANOVA.

As can be seen in Table 4, two-way interactions of Group (RA and CA controls) and Regularity level were significant for the five morpho-orthographic principles. These results indicated that the discrepancy between the two-regularity levels were significantly higher among the RA-controls compared to the CA-controls. In addition, the two-way interactions of Group (DD, CA-controls) and Regularity level were significant for all morpho-orthographic principles except for the transparency of the affix envelope principle. These results indicated that the discrepancy between the two-regularity levels was significantly higher among the DD children compared to the CA-controls. Furthermore, the two-way interactions of Group (DD, RA-controls) and Regularity level were significant for the two morpho-orthographic principles: transparency of the affix envelope and affix letter prevalence principles. The results indicated that while the discrepancy between the two-regularity levels was significantly higher among the sixth grade DD children compared to the RA-controls with regard to the affix letter prevalence principle, the discrepancy between the two-regularity levels was significantly higher among the RA-controls compared to the sixth grade DD children with regard to the transparency of the affix envelope principle.

Finally, it should be noted that the effect sizes of the discrepancy between the two-regularity levels were high among all three groups and in each of the five morpho-orthographic principles. It was found that the discrepancy between the two-regularity levels was not significant only among the CA-controls and only with regard to the phono-morpho orthographic consistency principle.

Discrepancy between spelling performance of infrequent words with regular and irregular affixes

Table 5 presents the results of the spelling performance of the three study groups on the infrequent words with regular and irregular affix spelling on.

The results of the two-way (3 × 2) mixed ANOVA with Group (DD, RA-controls, CA-controls) as the between-subject factor and the Regularity level (Regular, Irregular) as the within subject factor, indicated significant main effects of Group for the five morpho-orthographic principles as follows: transparency of the affix envelope, $F(2,65) = 99.78$, $p < .001$, $\eta_p^2 = 0.75$, affix letter prevalence, $F(2,65) = 105.48$, $p < .001$, $\eta_p^2 = 0.76$, morpho-phonological competition, $F(2,65) = 48.67$, $p < .001$, $\eta_p^2 = 0.60$, overtness of the phonological-orthographic, $F(2,65) = 49.62$, $p < .001$, $\eta_p^2 = 0.60$ and phono-morpho-orthographic consistency, $F(2,65) = 35.36$, $p < .001$, $\eta_p^2 = 0.52$. Scheffé post-hoc analyses indicated that the performance scores of the children in the DD group were significantly lower than the RA and CA controls ($p < .01$) in all five morpho-orthographic principles. Furthermore, the scores of the RA-controls were significantly lower than the scores of the CA-controls ($p < .001$).

In addition, the results of the two-way (3 × 2) mixed ANOVA indicated significant main effects of Regularity level for the five morpho-orthographic principles as

Table 5 Descriptive statistics, effect sizes and F-values of the discrepancy between spelling performance in non-frequent words with regular and irregular morpho-orthographic principles

Morpho-orthographic principles	Group	Regular		Irregular		*t*	Cohen's d	F-values (Group*Regularity)		
		Mean (%)	SD	Mean (%)	SD			DD & RA	DD & CA	RA & CA
Transparency of the affix envelope	DD	55.67	14.46	42.75	9.05	4.21***	0.92	44.08***	1.92	30.19***
	RA-controls	82.43	9.06	44.44	13.10	16.69***	3.48			
	CA-controls	96.23	2.94	77.69	13.88	6.89***	1.41			
Affix letter prevalence	DD	84.19	9.47	31.08	13.24	19.79***	4.32	9.25**	190.43***	152.21***
	RA-controls	89.71	8.64	46.75	11.87	21.06***	4.39			
	CA-controls	96.14	4.51	87.01	7.99	4.97***	1.01			
Morpho-phonological competition	DD	59.29	10.40	33.10	11.23	15.52***	3.39	1.14	63.96***	75.45***
	RA-controls	88.48	6.23	59.57	10.76	15.33***	3.20			
	CA-controls	94.89	4.00	88.68	8.26	3.43**	0.70			
Overtness of the phonological-orthographic link	DD	53.33	9.92	15.71	16.30	13.07***	2.85	7.60**	49.75***	90.16***
	RA-controls	67.79	9.10	18.16	17.55	15.30***	3.19			
	CA-controls	95.46	4.56	85.28	11.07	3.88***	0.79			
Phono-morpho-orthographic consistency	DD	58.54	9.45	29.41	19.14	7.74***	1.69	.28	54.36***	82.34***
	RA-controls	78.43	9.00	51.70	12.71	10.54***	2.20			
	CA-controls	93.67	5.32	92.28	5.93	1.11	0.23			

*$p < .05$, **$p < .01$, ***$p < .001$

follows: transparency of the affix envelope, $F(1,65) = 223.36$, $p < .001$, $\eta_p^2 = 0.78$, affix letter prevalence, $F(1,65) = 774.35$, $p < .001$, $\eta_p^2 = 0.92$, morpho-phonological competition, $F(1,65) = 382.88$, $p < .001$, $\eta_p^2 = 0.86$, overtness of the phonological-orthographic, $F(1,65) = 368.48$, $p < .001$, $\eta_p^2 = 0.85$ and phono-morpho-orthographic consistency, $F(1,65) = 159.29$, $p < .001$, $\eta_p^2 = 0.71$. The results indicated higher spelling scores when the affix letter was regular compared to irregular morpho-orthographic form.

Finally, the two-way interactions of Group and Regularity level were significant for the five morpho-orthographic principles as follows: transparency of the affix envelope, $F(2,65) = 23.88$, $p < .001$, $\eta_p^2 = 0.42$, affix letter prevalence, $F(2,65) = 113.12$, $p < .001$, $\eta_p^2 = 0.78$, morpho-phonological competition, $F(2,65) = 48.67$, $p < .001$, $\eta_p^2 = 0.60$, overtness of the phonological-orthographic, $F(2,65) = 49.62$, $p < .001$, $\eta_p^2 = 0.60$ and phono-morpho-orthographic consistency, $F(2,65) = 35.36$, $p < .001$, $\eta_p^2 = 0.52$. As mentioned above, we further examined the differences in the performance scores on the homophonous affix spelling task between the two groups using a two-way (2×2) mixed ANOVA.

As can be seen in Table 5, two-way interactions of Group (RA and CA controls) and Regularity level were significant for the five morpho-orthographic principles. These results indicated that the discrepancy between the two-regularity levels was significantly higher among the RA-controls compared to the CA-controls. In addition, the two-way interactions of Group (DD, CA-controls) and Regularity level were significant for all morpho-orthographic principles except for the transparency of the affix envelope principle. These results indicated that the discrepancy between the two-regularity levels was significantly higher among the DD children compared to the CA-controls. Furthermore, the two-way interactions of Group (DD, RA-controls) and Regularity level were significant for the three morpho-orthographic principles: transparency of the affix envelope, affix letter prevalence, and overtness of the phonological-orthographic principles. The results indicated that the discrepancy between the two-regularity levels was significantly higher among the RA-controls compared to the DD children in all three principles.

Finally, it should be noted that the effect sizes of the discrepancy between the two-regularity levels were high among all three groups and in each of the five morpho-orthographic principles. The discrepancy between the two-regularity levels was not significant only among the CA-controls and only with regard to the phono-morpho orthographic consistency principle.

Discrepancy between spelling performance according to Group, regularity and frequency

Although there were no hypotheses in the current study regarding to the discrepancy between spelling performance according to Frequency level, we conducted three-way ($3 \times 2 \times 2$) mixed ANOVA with Group (DD, RA-controls, CA-controls) as the between-subject factor and the Regularity level (Regular, Irregular) and Frequency level (frequent, infrequent) as the within subject factors. Significant three-way interactions indicated that the discrepancy between the spelling performance of words

with regular and irregular affix spelling differ as a function of the word frequency (See Tables 6, 7).

The results indicated significant three-way interactions only for the two morpho-orthographic principles: affix letter prevalence, $F(2,65) = 4.83$, $p < .01$, $\eta_p^2 = 0.13$ and overtness of the phonological-orthographic link, $F(2,65) = 9.05$, $p < .001$, $\eta_p^2 = 0.22$. The differences in spelling performance of homophonous affix letters between two Regularity levels and the two Frequency levels were further examined using a two-way (2×2) mixed ANOVA for each study group. The two-way interactions of Regularity level and Frequency level were significant for the two morpho-orthographic principles only among the DD students [affix letter prevalence, $F(1,20) = 30.88$, $p < .001$, $\eta_p^2 = 0.61$ and overtness of the phonological-orthographic link, $F(1,20) = 17.46$, $p < .001$, $\eta_p^2 = 0.47$] and the RA-controls [affix letter prevalence, $F(1,22) = 17.16$, $p < .001$, $\eta_p^2 = 0.44$ and overtness of the phonological-orthographic link, $F(1,22) = 33.28$, $p < .001$, $\eta_p^2 = 0.60$], but not among the CA-controls [affix letter prevalence, $F(1,23) = 1.64$, $p = .213$, $\eta_p^2 = 0.07$ and overtness of the phonological-orthographic link, $F(1,23) = 2.46$, $p = .131$, $\eta_p^2 = 0.10$]. These results indicated a higher effect of Regularity level for infrequent words compared to frequent words among the DD students and among RA-controls as well as a higher effect of Frequency level for irregular words compared to regular words.

Discussion

Intrinsic to the development of reading and spelling is the ability to acquire the associations between units of oral language and their written representations. This skill benefits not only from explicit instruction but also from implicit statistical learning (Treiman, 2018). The extraction of regularities from sequential stimuli assists learners in predicting future co-occurring elements (Conway, 2020). According to this view, children learn the co-occurring letter sequences based on their exposure frequency to written words present in their environment (Bogaerts et al., 2021; Elleman et al., 2019; Sawi & Rueckl, 2019). Building upon the work of Schiff et al. (2020), we designed an experiment to further investigate how 6th graders with dyslexia cope with affix letter spelling in Hebrew compared to reading-level and chronological age-matched controls. This study was a specific attempt to clarify the types of morphological patterns that dyslexics find difficult to acquire.

When examining the difference between the three groups on the proportion of overall correct items on the spelling test, the performance of the DD students was significantly lower than the performance of the RA- and CA-controls. However, an examination of each hypothesis separately yielded a different picture: 4 out of the 5 hypotheses have been confirmed, indicating that spelling performance in children with dyslexia is similar to the typically developing younger controls. Such findings are consistent with the notion that individuals with dyslexia are able to pick up morphological regularities to assist their spelling performance as a function of their exposure to morpho-orthographic patterns from written input. Namely, spelling performance is influenced by both characteristics of the child as well the input (Casalis et al., 2011). Therefore, sensitivity to lower-frequency or irregular morphological

Table 6 Descriptive statistics, effect sizes and t-values of the discrepancy between spelling performance on frequent and non-frequent words with regular morpho-orthographic principles

Morpho-orthographic principles	Group	Frequent		Non-frequent		*t*	Cohen's d
		Mean (%)	SD	Mean (%)	SD		
Transparency of the affix envelope	DD	62.76	14.67	55.67	14.46	4.50***	0.98
	RA-controls	83.53	10.56	82.43	9.06	.78	0.16
	CA-controls	97.75	2.76	96.23	2.94	2.44*	0.50
Affix letter prevalence	DD	87.07	9.03	84.19	9.47	2.37*	0.52
	RA-controls	91.01	8.59	89.71	8.64	1.06	0.22
	CA-controls	98.73	1.50	96.14	4.51	2.86**	0.58
Morpho-phonological competition	DD	72.95	13.31	59.29	10.40	7.44***	1.62
	RA-controls	90.35	7.96	88.48	6.23	1.19	0.25
	CA-controls	96.94	3.21	94.89	4.00	2.96**	0.60
Overtness of the phonological-orthographic link	DD	57.90	11.46	53.33	9.92	4.27***	0.93
	RA-controls	73.99	12.25	67.79	9.10	3.35**	0.70
	CA-controls	96.37	3.80	95.46	4.56	.80	0.16
Phono-morpho-orthographic consistency	DD	65.24	11.13	58.54	9.45	5.25***	1.15
	RA-controls	81.13	10.22	78.43	9.00	1.63	0.34
	CA-controls	96.15	3.14	93.67	5.32	2.23*	0.45

*$p < .05$, **$p < .01$, ***$p < .001$

Table 7 Descriptive statistics, effect sizes and t-values of the discrepancy between spelling performance on frequent and non-frequent words with irregular morpho-orthographic principles

Morpho-orthographic principles	Group	Frequent		Non-frequent		*t*	Cohen's d
		Mean (%)	SD (%)	Mean	SD		
Transparency of the affix envelope	DD	53.51	10.64	42.75	9.05	4.03***	0.88
	RA-controls	51.14	17.30	44.44	13.10	2.71*	0.57
	CA-controls	86.90	11.52	77.69	13.88	3.18**	0.65
Affix letter prevalence	DD	43.61	15.66	31.08	13.24	7.91***	1.73
	RA-controls	57.55	17.56	46.75	11.87	4.76***	0.99
	CA-controls	91.84	6.80	87.01	7.99	3.11**	0.64
Morpho-phonological competition	DD	51.75	14.27	33.10	11.23	13.35***	2.91
	RA-controls	64.08	15.98	59.57	10.76	2.10*	0.44
	CA-controls	93.05	5.92	88.68	8.26	2.86**	0.58
Overtness of the phonological-orthographic link	DD	38.57	23.71	15.71	16.30	5.36***	1.17
	RA-controls	50.19	20.86	18.16	17.55	7.87***	1.64
	CA-controls	89.94	9.04	85.28	11.07	2.48*	0.51
Phono-morpho-orthographic consistency	DD	41.33	21.53	29.41	19.14	4.05***	0.88
	RA-controls	61.04	20.22	51.70	12.71	3.10**	0.65
	CA-controls	95.86	6.24	92.28	5.93	3.04**	0.62

*$p < .05$, **$p < .01$, ***$p < .001$

pattern would develop over more time. Overall, the findings support the idea that sensitivity to morpho-orthographic regularities in spelling in children with dyslexia is characterized by delayed rather than atypical development (Bourassa et al., 2019).

Our first hypothesis concerned the discrepancy between regular and irregular affix spelling in the affix envelope transparency category. This hypothesis was not confirmed, as the DD and CA-controls presented similar discrepancies, while the RA-controls differed from the DD group and CA-controls. Our results show that compared to RA- and CA-controls, the most challenging affix principles for 6th graders with dyslexia regardless of word frequency is the transparent, demarcated envelope – as the DD are quite insensitive to the affix envelop, they do not pay attention to word morphology and to the difference between the stem and the suffix in both the regular and irregular conditions. Importantly, our results indicate that CA-controls are also unaffected by regularity—but due to another reason; The small discrepancy between performance on words with transparent and non-transparent affix envelopes indicates that CA-controls are familiar with the irregular condition in which the separation of the root from the affix borders is opaque. RA-controls, in contrast, present larger discrepancies in performance between spelling regular and irregular affixes. For instance, in cases of morphological metathesis such as *hishtatef* 'participate', the root radical *sh* exchanges place with the affixal *t*, so it may not be clear to DD students whether the *t* is affixal (and thus has only one possible spelling as ת), or a root letter (and thus has two possible spellings as ט or ת). These irregular affix spelling patterns, requiring particular knowledge of specific morpho-phonological structures, challenge RA-controls who have not been exposed to an adequate number of similar structures to help them discern the affix. Thus, these findings suggest that typically developing 6th graders are sensitive to the morphological structure of written Hebrew words and make efficient use of it to spell homophonous words, whereas 6th graders with dyslexia are not able to do that, and younger, typically developing Hebrew-speaking children are yet to discern irregular structure and overcome opacity.

Our second hypothesis predicted that the discrepancy between regular and irregular affix spelling in the affix letter prevalence criterion would be similar in the DD and RA-control groups, and higher among CA-controls. This hypothesis was partially confirmed, as the differences in affix spelling performance between the DD group and RA-controls on this criterion were marginally significant. In other words. compared to RA-controls, students with dyslexia were aided to some extent by the principle of affix letter frequency. The discrepancy in this category between regular and irregular affix spelling indicates that compared to CA-controls and (to some extent) RA-controls, 6th graders with dyslexia have yet to acquire irregular affixal forms. Similarly, sensitivity to morpho-graphemic regularities in reading and spelling among Italian children with dyslexia also emerged as a function of high-frequency morphological constituents during new stimuli processing (Angelelli et al., 2017). This analysis, too, indicated a lesser morphological ability in the DD students.

The third hypothesis presumed that the discrepancy between regular and irregular affix spelling would be similar in the DD and RA-control groups and higher among CA-controls in words that demonstrate the morpho-phonological affix competition

criterion. This hypothesis has been confirmed, as our analysis shows that in both frequent and infrequent words, the dyslexic and RA-controls showed similar sensitivity to the criteria of internal morphological competition, which was lower than that of CA-controls. Namely, both the dyslexic and reading-age matched children performed better when spelling affixes with no internal competitor affix; and for both groups, performance in case of competition fell below performance for its absence, indicating that the higher the irregularity in spelling, the larger the discrepancy between the spelling performance on words with regular and irregular affix spelling.

Indeed, studies with typically developing children have shown that the multiplicity of alternative orthographic representations makes it more difficult for learners to recognize conventional spelling (Rahmanian & Kuperman, 2019; Sandra, 2010; Sandra et al., 1999; Sandra & Van Abbenyen, 2009). Other examples of contradictory information that hinders experienced spellers come from Sandra and his colleagues (1999). For example, Dutch marks the 3rd person verbal form in the present tense by adding a suffix. However, due to final devoicing, in some verbs the affix does not change the verb pronunciation, resulting in homophony. In such verbs, spelling error are more abundant even among experienced writers (Gillis & Ravid, 2006). Experimental studies by Sandra et al. have indicated the role of affix frequency in spelling performance overriding transparent morphological rules (Sandra, 2010; Sandra et al., 1999; Sandra & Van Abbenyen, 2009).

To some extent, these findings align with Rahmanian and Kuperman's (2019) study which investigated homophonous spelling errors in English. Their findings suggest that the high frequency of spelling errors in a corpus of unedited texts relative to the frequency of the standard form made it more difficult for learners to identify the correct form. Thus, repeated exposure to substandard spelling patterns may act like morpho-phonological competition that can prompt the formation of alternative orthographic representations in the mental lexicon of the reader and hinder the selection of correct spelling patterns.

In our fourth hypothesis, we predicted similar discrepancies between regular and irregular affix spelling in the phonological-orthographic link overtness criterion among the DD and RA-control groups. We found that in frequent words, this prediction was supported, as the morpho-orthographic principle of overt phonology was found to similarly affect the spelling performance of dyslexic and RA-controls. That is, in both these groups, compared to younger CA-controls, considerably more accurate spelling was found in words in which the affix letter represented a phonological segment compared to words in which the orthographic segment did not. The overt phonology category involves the spelling of vowel letters. Studies suggest that vowels and consonants are processed by different neuronal systems in the brain (Carreiras et al., 2007, 2009; Carreiras & Price, 2008; Nazzi & New, 2007; Tainturier & Rapp, 2004). Thus, vowels may be more or less challenging to spell compared to consonants, depending on the characteristics of the language. In some languages, including Spanish, vowels are easier for children to spell than consonants (Zhang et al., 2021). In other languages, including French, consonants are mapped more clearly and regularly onto graphemes, while vowels often have multiple, even opaque relationships with the graphemes and orthographic segments that represent them in writing (e.g., Lehtonen & Bryant 2005a, 2005b; Nag et al., 2010; Treiman

& Kessler, 2006). In such languages, written vowel representation is likely to be acquired later than that of consonants, whether in spelling (Miceli et al., 2004) or in processing words while reading (Winskel & Lemwanthong, 2010). For example, in a study conducted among French-speaking children on the acquisition of silent-letter endings (Sénéchal et al., 2016) confirmed that 1st, 2nd, and 3rd grade children have difficulty using silent letter endings when spelling pseudowords, as the absence of phonological cues makes it harder to retrieve the silent forms from memory.

This challenge is further exacerbated in the case of Hebrew, where vowels are often not represented at all in writing, or else are given only partial and inconsistent representation, as in words in the overt/covert phonology principle in our study (Ravid, 2012) where letters may not represent a phonological segment, e.g., *-av* spelled with ־, normally reflecting the vowel i. The fact that these types of errors persevere in students with dyslexia despite frequent exposure to written language throughout elementary school, suggests that they continue to depend on transparent phoneme-grapheme correspondences in trying to spell the target word (Law et al., 2018; Snowling, 2000). These less mature strategies found in the spelling of homophones may have resulted from limited morphological analysis and incomplete word familiarity.

A similar pattern of findings as in the morpho-phonological competition criterion was detected in the criterion of phono-morpho-orthographic consistency, indicating the confirmation of **our fifth hypothesis**. As predicted, similar discrepancies were found between regular and irregular affix spelling in the phono-morpho-orthographic consistency criterion among the DD and the two control groups. It appears that Hebrew-speaking dyslexic spellers in the 6th grade are likely to be challenged in the same way as typically developing 2nd graders by situations in which a strong morphological generalization is violated, while in typically developing 6th graders this regularity effect disappears. For example, the final ה generalization that applies to most singular feminine nouns is a cause of spelling errors in masculine verbs with a final *-a*, as described above. Such errors are quite common in the early grades, as acquiring this knowledge requires further morphological learning and more experience with written Hebrew patterns. This result concurs with the idea that efficient learning from written linguistic input relies on multiple types of statistical regularities, including frequency of letter co-occurrences, phoneme-to-grapheme correspondence, morphological regularities, etc. (Bogaerts et al., 2021).

Although we had no specific hypotheses regarding the effect of word frequency on spelling performance, post-hoc analyses revealed yet another similarity between the DD and younger RA-control groups. The results of the post-hoc analyses indicated that the discrepancy between the spelling performance of words with regular and irregular affix spelling differs as a function of the word frequency only for the criteria of affix letter prevalence and overtness of the phonological-orthographic link. However, the differences in spelling performance of homophonous affix letters between the two Regularity and the two Frequency levels were significant only among the DD students and the RA-controls. In other words, when word frequency decreases, the magnitude of the regularity effect is greater; and vice versa, when affix spelling regularity decreases, the magnitude of the frequency effect is greater.

In CA-controls, no regularity effect was observed for infrequent words, compared to frequent words, and no higher effect of frequency was found for irregular words compared to regular words.

Why do the similarities between the performance patterns of children with dyslexia and reading level-matched controls on the affix spelling test show up mostly in words with and without internal competition and phono-morpho-orthographic consistency? Two relevant explanations can be offered. First, the findings that dyslexic spellers generally did not consistently differ from the reading age-matched controls may be related to the observation that 2nd graders are still struggling with some aspects of affix spelling (Diamanti et al., 2017; Schiff et al., 2020; Van den Broeck & Geudens, 2012), and that this is indeed a genuine obstacle for dyslexic and reading-level matched controls alike.

Second, the similarities between the performance patterns of children with dyslexia and reading level-matched controls may have to do with the role of morphological strategies in spelling performance. Various studies have shown that children with dyslexia use morphology to the same extent as (or more than) younger typically developing children (e.g., Bourassa & Treiman 2008; Diamanti et al., 2014; Hauerwas & Walker, 2003, Quémart & Casalis, 2017). Findings from the current study further corroborate the importance of morphological awareness skills in a morphically rich language such as Hebrew, lending support to the notion that morphological knowledge assists both students with dyslexia and typically-developing reading-age controls in all but one affix spelling category—the affix envelope transparency. Research has shown that discerning the separation between the affix and the base word is quite challenging for dyslexic individuals who present reduced analytical morphological abilities in Hebrew (Schiff & Ravid, 2007).

Our study constitutes a methodological contribution toward the measurement of spelling performance. Previous studies of spelling ability have mostly relied on spelling accuracy and a simple percent of correct responses to reflect spelling skills (e.g., Alves et al., 2016; Kohnen et al., 2015; Wanzek et al., 2017), providing minimal information about the specific spelling regularity with which poor spellers struggle. In the current study, analysis of spelling errors was conducted using a novel coding system of morpho-orthographic criteria exclusive to affix spelling in Hebrew. The misspellings produced revealed that children with dyslexia tend to rely on probabilistic information when spelling words with unpredictable affixes. These results align with Marinelli et al. (2021), who showed that children with dyslexia are able to extract irregular spelling regularities from written stimuli. However, for some morphological regularities, this sensitivity is related to prolonged experience with atypical mappings and word frequency, leading to the development of whole-word lexical representation. Altogether, this evidence supports the hypothesis that students with dyslexia do rely on frequently occurring patterns when trying to achieve spelling accuracy (Perfetti, 2007; Perfetti & Hart, 2002).

However, our study also has limitations that restrict its generalizability. First, the study was conducted with Hebrew-speaking children, limiting the generalizability of the specific principles to other languages. Extending the investigation to similar categories in additional orthographies and grammatical systems (as in Gillis &

Ravid 2006) will enable drawing more definitive conclusions regarding the learning of morpho-orthographic regularities among children with dyslexia. Another constraint on generalizability is that the dyslexic participants and the RA-controls were matched by reading ability. Future studies should verify that the groups are as similar as possible in both their reading and spelling abilities before the beginning of the study. Finally, our task may not be sufficiently representative of the individual's general capacity to learn morpho-orthographic regularities. A specific spelling task cannot be predictive of the entire capacity to learn linguistic regularities. Since statistical learning tasks have been found to be context-specific (Frost et al., 2015), and since individuals differ in their general ability to learn regularities, an interesting avenue might be to examine the acquisition of spelling regularities among children with dyslexia within the morphological root that is considered more challenging to acquire than affixal letters.

Finally, we discuss the implications of our findings for spelling acquisition. Altogether, it seems that dyslexic children's spelling accuracy of affixal morpho-orthographic principles is similar to that of children of the same reading level, and lower than that of children of the same chronological age, who are generally better spellers. It is likely that among Hebrew-speaking children with dyslexia, spelling words with derivational suffixes develops across the upper elementary grades. This means that 6th grade students with dyslexia continue to need explicit spelling instruction as an integral part of learning new vocabulary even in the upper elementary school grades (Bahr et al., 2020). Language teachers might thus incorporate word morphology methods into their teachings while combining in-depth instruction of metacognitive strategies to support vocabulary knowledge and specific word spelling strategies (Crosson et al., 2019; Galuschka et al., 2020). To address their specific spelling deficits, children with dyslexia should receive word spelling training programs that expose them to both regular affixal spelling patterns, while teaching them to extract morphological regularities as well as irregular affixal structures. This may assist in strengthening the connection between dyslexic students' phonological awareness, orthographic representations, and morphological knowledge.

Appendix 1: Word frequencies for frequent words

Words	Gloss	M	SD	Words	Gloss	M	SD	Words	Gloss	M	SD
אבשל	I will cook	5.00	0.00	זכרת (ז)	You remembered	5.00	0.00	קונה (ז)	Buys	5.00	0.00
אדבר	I will talk	5.00	0.00	חזאי	Weather reporter	4.30	0.48	קנתה	She bought	5.00	0.00
אדומות	Red, Pl.Fm	5.00	0.00	חכמות	Smart,Pl.Fm	5.00	0.00	ראיתיך (ז)	I saw you	4.10	0.32
אזרוק	I will throw	5.00	0.00	חשמלאי	Electrician	5.00	0.00	ראתה	She saw	5.00	0.00
אחותה	Her sister	4.80	0.42	יבכה	Wail	5.00	0.00	רגליך (ז)	Your feet	4.50	0.53
אחיותיך (נ)	Your, Fm sisters	4.60	0.52	ידיך (נ)	Your,Fm hands	4.50	0.53	רושמות	Taking note, Fm. Pl	4.90	0.32
אצלכן	At-yours,Fm	4.80	0.42	יזרוק	He will throw	5.00	0.00	שאלתיו	I asked him	4.10	0.32
בונה (ז)	He is building	5.00	0.00	ילדיך (ז)	Your children	4.50	0.53	שמיכת	Blanket of	5.00	0.00
בנתה	She built	5.00	0.00	ילדך	Your child	4.50	0.53	שמעתיך (ז)	I heard you	4.00	0.00
גזרתי	I cut	5.00	0.00	ילדכם	Your,Pl child	4.50	0.53	שמרה	She kept	4.90	0.32
דרכך (נ)	Your, Fm way	4.10	0.32	ישאל	He will ask	5.00	0.00	שמרתיך (נ)	I kept you,Fm	4.00	0.00
הגזמת (ז)	You have exaggerated	4.30	0.48	יתנגב	He will towel himself	5.00	0.00	שנתי	I slept	4.50	0.53
הגזמתי	I have exaggerated	4.30	0.48	יתקצר	It will shorten	5.00	0.00	שקית	Baggie	5.00	0.00
הגיש	He delivered	5.00	0.00	יתקשר	He will call	5.00	0.00	תבשל	She will cook	5.00	0.00
הוריך (נ)	Your,Fm parents	4.50	0.53	כאחיה	Like her brothers	4.10	0.32	תופעה	Phenomenon	4.60	0.52
הכעיס	He made x angry	5.00	0.00	כבאי	Firefighter	5.00	0.00	תוצאה	Result	5.00	0.00
הלבשת	You dressed x up	5.00	0.00	כוסית	Small glass	5.00	0.00	תזרוק	She will throw	5.00	0.00
הלכה	She went	5.00	0.00	כיתתי	My class	4.30	0.48	תלבושת	Uniform	5.00	0.00
העלבת (ז)	You have offended	5.00	0.00	כסאה	Her chair	4.00	0.00	תלמיד	Pupil	5.00	0.00
הפליג	He sailed	4.30	0.48	כפית	Tea spoon	5.00	0.00	תנועה	Movement	5.00	0.00
הצטלם	He was photographed	5.00	0.00	כתבת (ז)	You wrote	5.00	0.00	תסתפר	He got a haircut	5.00	0.00
הצטנן	He got a cold	5.00	0.00	כתבת (נ)	You, Fm wrote	5.00	0.00	תפילה	Prayer	4.70	0.48
הצטער	He was sorry	5.00	0.00	להגביר	To turn up	4.30	0.48	תצייר	Straw	5.00	0.00
הציע	He suggested	4.70	0.48	להרכיב	To assemble	4.30	0.48	תרגיל	Exercise	4.30	0.48
הרגשתם	You,Pl felt	5.00	0.00	להשתיק	To silence	5.00	0.00	תרומה	Donation	4.30	0.48
הרכבתיו	I put it together	4.10	0.32	לקחתיו	I took it/him	4.80	0.42	תשובה	Response	5.00	0.00
השפיע	He influenced	4.70	0.48	לקנות	To buy	5.00	0.00	תשתדל	She will make an effort	5.00	0.00
התבטל	It was canceled	4.80	0.42	לראות	To see	5.00	0.00	תשתמש	She will use	5.00	0.00
התגלגלתם	You, Pl have rolled	5.00	0.00	לשחות	To swim	5.00	0.00				
התחלתי	I started	5.00	0.00	מברשת	Brush	5.00	0.00				
התלבשת (ז)	You got dressed	5.00	0.00	מודיע	Announces	5.00	0.00				
התלהבות	Enthusiasm	4.80	0.42	מורה (ז)	Teacher	5.00	0.00				
התנדנד	Swung	5.00	0.00	מלחמה	War	5.00	0.00				
התעמלות	Exercise	5.00	0.00	מלכת	Queen of	4.50	0.53				
התקשרת (נ)	You,Fm called	5.00	0.00	מצאתיו	I found it/him	4.10	0.32				
התרגשות	Excitement	4.80	0.42	מצאתם	You,Pl have found	5.00	0.00				
התרחץ	He washed	5.00	0.00	מרפסת	Balcony	5.00	0.00				
ובחצר	And in the yard	4.60	0.52	משחקיה	Playroom	5.00	0.00				
וברך	And knelt	4.10	0.32	משחקיו	His games	4.10	0.32				
ובשלווה	And with calm	4.30	0.48	משקפיו	His glasses	4.10	0.32				
וכאביו	And his pains	4.10	0.32	משקפת	Goggles	5.00	0.00				

וכאחותה	And at her sister	4.00	0.00	נעליו	His shoes	4.10	0.32				
וכתבה	And she wrote	4.90	0.32	ספריך (ז)	Your books	4.20	0.42				
ומחר	And tomorrow	4.90	0.32	עבודתכם	Your,Pl wotk	4.10	0.32				
וצנונית	And a radish	5.00	0.00	עליך (ז)	On you	5.00	0.00				
ורקדה	And she danced	5.00	0.00	פתחת (ז)	You have opened	5.00	0.00				
ותמרים	And materials	4.90	0.32	קבוצתי	Of group	4.60	0.52				

Appendix 2: Word frequencies for infrequent words

Words	Gloss	M	SD	Words	Gloss	M	SD	Words	Gloss	M	SD
אבטח	I will trust	1.50	0.53	וכלשונו	And in its language	1.40	0.52	סברה	Dammed	1.20	0.42
אבלום	I will block	1.90	0.32	ומפרשי	And my sail	1.10	0.32	פינתי	Corner,Adj	2.00	0.00
אהבתיך (נ)	I loved you,Fm	1.20	0.42	וקצפה	And her rage	1.10	0.32	פצתה	She uttered	1.20	0.42
אחסנה	I will innocula te her	1.00	0.00	ורמסו	And trampled,Pl	1.20	0.42	פקוחות	Wide open, Pl.Fm	1.80	0.42
אישיותך (ז)	Your personal ity	1.50	0.53	ותחביר	And syntax	1.20	0.42	פרשת	The tale pf	2.00	0.00
אמרותיו	His sayings	1.00	0.00	ותשורות	And gifts	1.20	0.42	ציפיותי ך (נ)	Your,Fm expectatio ns	1.80	0.42
אשקוד	I will labor	1.00	0.00	זהובות	Golden	1.80	0.42	ציפית	You expected	2.00	0.00
בדידותך (נ)	Your,Fm loneline ss	1.50	0.53	זיהיתיו	I identified him	1.30	0.48	צלחתם	Their plate	1.20	0.42
בוטה (ז)	Blunt	1.20	0.42	חוויתי	I experienced	2.00	0.00	צליחת	The crossing of	1.10	0.32
בינך (ז)	Between you	1.90	0.32	חלמת (ז)	Ou have dreamt	2.00	0.00	שגרתי	Ruotine	2.00	0.00
ברכותיך (ז)	Your blessing s	1.40	0.52	חקלאי	Agriculture worker	2.00	0.00	שיקולי ך (ז)	Your considerat ions	1.90	0.32
בשרה	Her flesh	1.20	0.42	טיעוניה	Her claims	1.50	0.53	שמאי	Appraiser	1.60	0.52
גאלתיו	I redeeme d him	1.10	0.32	יבטח	Yacht	1.90	0.32	תבואה	Cereals	1.50	0.53
גלימת	Robe	1.30	0.48	יומנאי	Desk officer	1.50	0.53	תבונה	Wisdom	1.70	0.48
גנזת (נ)	You,Fm archived	1.00	0.00	ימרוד	Will rebel	2.00	0.00	תבטח	She will trust	1.70	0.48
גשומות	Rainy,Pl. Fm	2.00	0.00	ישקוד	Will work industriously	1.90	0.32	תביעה	Suing	2.00	0.00
דאגתכם	Your,Pl concern	1.50	0.53	יתגבש	Will consolidate	2.00	0.00	תבלמי	You,Fm will block	1.70	0.48
דוגמית	Sample	1.70	0.48	יתמזל	Will be lin luck	1.60	0.52	תוכנית ה	Her plan	1.50	0.53
דלתה	Her door	1.70	0.48	יתנער	Will shrug off	1.60	0.52	תולדה	Outcome	1.10	0.32
הגיגיך (נ)	Your,Fm deliberat ions	1.00	0.00	כארי	As a lion	1.10	0.32	תחושת ך	Your feeling	1.50	0.53
הומה (ז)	Noisy	1.30	0.48	ככתבו	Exactly as written	1.10	0.32	תכונה	Property	2.00	0.00

החלמת	You have recovered	1.80	0.42	לדלות	To glean	1.20	0.42	תמריץ	Incentive	2.00	0.00
הכניע	He suppressed	1.70	0.48	להלהיב	To cause enthusiasm	2.00	0.00	תסתבך	Got entangled	2.00	0.00
הללתיך (ז)	I praised you	1.00	0.00	להמחיש	To make tangible	2.00	0.00	תסתגל	You will adjust	2.00	0.00
המטיר	He showered rain on x	1.60	0.52	להסגיר	To turn in,Tr	2.00	0.00	תקדים	Precedent	2.00	0.00
הנהגתם	You,Pl led	2.00	0.00	למנות	To enumerate	1.70	0.48	תקשורת	Communication	2.00	0.00
הפלגת (ז)	You sailed	1.40	0.52	למענכן	For you,Pl.Fm	1.60	0.52	תרועה	Loud cry	1.30	0.48
הצטבר	Accumulated	1.60	0.52	לפצות	To compensate	1.70	0.48	תרשים	Outline	1.50	0.53
הצטייר	Was portrayed	1.60	0.52	מבוקשכם	Your,Pl wishes	1.60	0.52	תשקוט	She will quiet down	1.10	0.32
הצטנף	Curled up	1.00	0.00	מונע	Prevents	2.00	0.00	תשתמט	You will shirk	1.50	0.53
הצלתיו	I saved him	1.40	0.52	מזחלת	Forgives,Fm	1.50	0.53				
הקריב	Sacrificed	1.30	0.48	מחצלת	Straw mat	1.60	0.52				
השביע	Administered an oath	1.60	0.52	מטלתה	Her assignment	1.00	0.00				
השכלת (ז)	You have become educated	1.20	0.42	מידותיך (ז)	Your sizes	1.10	0.32				
השכמת (ז)	You rose up early	1.20	0.42	מידותיך (נ)	Your,Fm sizes	1.10	0.32				
השכמתי	I rose up early	1.20	0.42	מימיו	His waters	1.10	0.32				
התבלט	Became prominent	1.70	0.48	מיניתיו	I appointed him	1.00	0.00				
התברך	Blessed oneself	1.70	0.48	מכרה (ז)	Mine	1.20	0.42				
התגמשות	Becoming flexible	1.50	0.53	מנתה	She enumerated	1.20	0.42				
התגנבת (נ)	You,Fm sneaked up	2.00	0.00	מפקדה	Headquarters	1.30	0.48				
התמניתי	I have been appointed	1.70	0.48	מקדמה	Down payment	1.60	0.52				
התנדף	Evaporated	1.30	0.48	מקטרת	Pipe	1.50	0.53				
התנהלתם	You,Pl managed yourselves	2.00	0.00	מרית	Spatula	1.60	0.52				
התפקדת (ז)	You counted yourself	1.20	0.42	נדודיו	His wanderings	1.00	0.00				
התפשרות	Reaching a compromise	1.30	0.48	נדרתי	I have vowed	1.10	0.32				
ובמחולות	And in dances	1.20	0.42	סברה	She considered	1.40	0.52				
ובעקרבים	And with scorpions	1.00	0.00	וכלשונו	And as said	1.10	0.32				

Appendix 3: Affix spelling task reliabilities

Frequent words -Regular.

1. Transparency of the affix envelope: α = 0.97.
2. Affix letter prevalence: α = 0.93.
3. Morpho-phonological competition: α = 0.82.
4. Overtness of the phonological-orthographic: α = 0.96.
5. Phono-morpho-orthographic consistency: α = 0.96.

Frequent words -Irregular.

1. Transparency of the affix envelope: α = 0.77.
2. Affix letter prevalence: α = 0.96.
3. Morpho-phonological competition: α = 0.98.
4. Overtness of the phonological-orthographic: α = 0.81.
5. Phono-morpho-orthographic consistency: α = 0.96.

Nonfrequent words -Regular.

6. Transparency of the affix envelope: α = 0.96.
7. Affix letter prevalence: α = 0.92.
8. Morpho-phonological competition: α = 0.78.
9. Overtness of the phonological-orthographic: α = 0.95.
10. Phono-morpho-orthographic consistency: α = 0.95.

Nonfrequent words -Irregular.

6. Transparency of the affix envelope: α = 0.71.
7. Affix letter prevalence: α = 0.95.
8. Morpho-phonological competition: α = 0.97.
9. Overtness of the phonological-orthographic: α = 0.84.
10. Phono-morpho-orthographic consistency: α = 0.96.

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