Rachel Schiff **Dorit Ravid**
Bar Ilan University **Tel Aviv University**

Vowel representation in written Hebrew: Phonological, orthographic and morphological contexts

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Address for correspondence:
Dr. Rachel Schiff
Director, Haddad Center
School of Education
Bar Ilan University
Ramat Gan 52900
Israel
Email: rschiff@mail.biu.ac.il

Abstract

The study investigates adult Hebrew readers' perception of words containing the grapheme ו in different orthographic and morphological contexts. In the first experiment, 38 third-year education students were asked to make lexical decisions regarding 24 pointed words (presented with vowel marks) in a sentential context in two conditions – with and without the grapheme ו standing for the vowels *o* and *u*. All words shared the same syllabic structure but had different morphological structures (linear and non-linear). Half of the words had ו which obligatorily occurs in all types of Hebrew script, while half of them had ו which is deleted in pointed script. Response latencies and accuracy were measured. In the second experiment, the same procedure was repeated using the same 24 words without pointing marks. The addition of ו was found to facilitate correct decision on task words. We also found that both orthographic and morphological contexts affected the representation of *o* and *u* by ו. We identified a category of Hebrew words where the status of ו is particularly unstable. The study supports a root-based view of Hebrew spelling and has implications for the interface of orthographic, phonological and morphological factors in the representation of written language. It also supports a reading / spelling processing model, which claims that internal orthographic representations of words are increasingly strengthened with each exposure during reading, but not all graphemes are strengthened equally. The general implication is that the ambiguities that exist in the relationships between orthography, phonology and morphology underlie spelling knowledge.

Keywords: Hebrew, orthography, phonology, vowels, morphology, resonance model.

Recent research on the development and processing of written Hebrew as well as writing in other languages (such as English and Kannada) indicates that consonants and vowels are represented and processed differently: Vowels are more problematic for readers, and particularly for poor readers, than consonants (Adams, 1990; Frost & Bentin, 1992; Landerl, Wimmer & Frith, 1997; Purushothama, 1990). Studies on the emergence and consolidation of Hebrew spelling indicate that vowel spelling is also acquired later and with more difficulty than consonant spelling (Ravid & Kubi, in press; Schiff, 2001; Seidman, 2001; Share & Levin, 1999). The focus of the current study is the domain of written vowels in Hebrew, and it aims to examine the effect of phonological, morphological and orthographic factors on how adults perceive words containing the letter ו.

Modern Hebrew employs two versions of the same orthography. One version, *pointed* orthography, represents both consonants and vowels. All consonants are represented by letters, while the five vowels *a,e,i,o,u* are represented by 13 diacritic marks termed *nikud* 'pointing'. This pointed version provides precise, in some cases redundant, phonological information about the written Hebrew word. It is used in reading and writing school instruction, in children's books, in texts for new immigrants, and in Biblical and poetic texts. A second orthographic version of Hebrew, the *non-pointed* orthography, represents all consonants by all letters, while vowels are partially and ambiguously represented by the letters AHWY[1], which serve a double function as designators of consonants and vowels (Hebrew אהוי). For example, both initial consonantal (or rather, semi-vowel) *y* and final vowel *i* in the word *yalduti* 'childish' are represented by the letter Y י (*Yod*) in the written string YLDWTY (Hebrew ילדותי). Non-pointed orthography is the default version of written

Hebrew, used across the board for most purposes, including school instruction from 4th grade onwards.

In spite of the fact that Modern Hebrew has two options of representing vowels, consonants are the more stable part of the written Hebrew word: Each and every consonant is represented in writing, though there are a number of homophonous graphemes. Vowels are relatively less stable in representation: The normally used non-pointed version over-represents consonants at the expense of vowels. Observation shows that Hebrew speakers, including teachers, often claim that they do not "hear vowels" when asked to segment words, and relate only to consonants. Note, for example, the non-pointed written string WKŠBMKTBYYK pronounced *uxšebemixtaváyix* 'and-when-in-your Fm Pl-letter-s' (Hebrew וכשבמכתביך): All of the consonants are represented in this written string, including the root morpheme K-T-B 'write' and affixal function elements - two conjunctions, a preposition, a pattern prefix, and a genitive suffix; but only two of the vowels (*u* and *i*) are represented in writing. Moreover, vowel representation is not consistent and systematic, depending on the vowel, on the grapheme representing it, on its morphological function, and on orthographic conventions, as shown in Table 1.

Table 1 summarizes the multiple functions of and constraints on AHWY as consonant and vowel designators in Modern Hebrew.

PLEASE INSERT TABLE 1 ABOUT HERE

The contribution of morphology

Studies on reading pointed and non-pointed Hebrew words indicate that single pointed words are read faster than non-pointed words, but when words are presented in context, the effect of pointing diminishes (Koriat, 1985; Navon & Shimron, 1985). Abu-Rabia's work on reading Arabic, another mainly consonantal Semitic language

which uses diacritics to disambiguate homophonous strings, also indicates a facilitating effect of pointing on readers, mediated by context (Abu-Rabia, 2001). In a recent study, Shimron (1999) found that pointing did not have a powerful effect on gradeschoolers' memory, and interacted with task conditions and reader skills. Shimron puts forth the idea that knowledge of Hebrew orthography is supplemented with important contributions from Semitic morphology, and that reading Hebrew leans heavily on syntactic and discourse cues in addition to phonological information. This idea is supported by a wide range of studies that point at the centrality of morphological structure and meaning in reading and writing Hebrew (Ben-Dror, Bentin & Frost, 1995; Frost, 1995; Frost, Forster & Deutsch, 1997; Ravid, 2001, 2002). These studies indicate that Hebrew readers/writers represent and analyze morphological structures in processing written words and texts, and that they employ morphological strategies in different ways than speakers of languages with less rich morphologies (Gillis & Ravid, 2000; Ravid & Bar-On, 2001).

Two morphological devices common in Hebrew are relevant here. One is the Semitic root-and-pattern structure, which combines root radicals (usually consonants) with a mainly vocalic pattern to produce a word. For example, root *g-d-l* takes adjectival pattern *CaCoC*[2] to create adjective *gadol* 'big', causative verb pattern *hiCCiC* to make verb *higdil* 'magnify', and abstract pattern *CóCeC* to create the abstract nominal *gódel* 'size'. Root and pattern affixation is considered non-linear since neither of the two morphological components appears in continuous form; rather, they are interdigitated within each other. A second word-formation device is the stem-and-suffix structure, which attaches a suffix to a base, usually a word. For example, the abstract suffix *–ut* may be attached to the adjective base *kal* 'easy' to produce *kal-ut* 'ease', and to the noun base *enoš* 'human' to produce *enoš-i* 'humane'.

This morphological device is linear in nature, since the two morphemes are distinct and follow each other in the word (Ravid, 1990).

The current study investigates the role of the Hebrew grapheme ו, standing for the vowels *o* and *u* in interaction with phonological, orthographic and morphological factors. Specifically, we are interested in the status of the letter ו as a consistent and an inconsistent element in the written word, and in its interaction with linear and non-linear morphological structure. This investigation was conducted in two different contexts: pointed and non-pointed words. Studies indicate that adult Hebrew readers are adept at reading non-pointed texts, employing "top-down" morphological, syntactic and discourse cues in retrieving vocalic patterns and assigning meaning to graphemic strings in their contexts (Frost & Bentin, 1992; Shimron, 1999). Frost (1995) showed that when reading non-pointed Hebrew words, the more missing vowels in the word, the higher the amount of ambiguity in the process of filling in the missing vowels and the slower the process of word recognition.

Phonology, morphology and orthographic conventions

In principle, vowels may be represented in four different ways in written Hebrew:

(1) *By pointing diacritic marks in pointed script*. For example, the two vowels *a* are represented in the pointed written string S_aP_aR *sapar* 'hairdresser' (Hebrew סַפָּר) by two diacritic marks.

(2) *By zero marking in non-pointed script*. For example, the two vowels *a* are represented in the non-pointed written string SPR *sapar* 'hairdresser' by zero marking (Hebrew ספר).

(3) *By the graphemes AHWY in non-pointed script*. For example, the vowels *i* and *u* are represented in the non-pointed written string *sipur* ‘story’ SYPWR by Y י and W ו respectively (Hebrew סיפור).

(4) *By a combination of pointing marks and AHWY in pointed script*, where AHWY are consistent (see below). For example, *yafe* ‘pretty’ is spelled Y_aP_eH (Hebrew יָפֶה); The string *Y_aP_e (Hebrew יָפֶ*) without the final H, though pointed, is incorrect.

AHWY and pointing interact with orthographic conventions in representing vowels. In general, vowel representation by AHWY at word final position in both pointed and non-pointed script is consistent, while representation of word-internal vowels is inconsistent or not permitted. The vowels *e,a* are usually marked by zero in word-internal position, and by A and H at word final position, e.g., *yafe* ‘pretty’, spelled YPH, Hebrew יפה. The vowels *i,u,o* are represented by W ו and Y י at any position in the word (and thus more often), e.g., *uvetoxo* ‘and-in-it’, spelled WBTWKW, Hebrew ובתוכו.

However AHWY and pointing marks carry more than phonological information: Their occurrence is closely linked to the morphological information expressed in the word. There are three morphological roles that AHWY can fulfill as *matres lectionis*, that is, ‘mothers of reading’ - AHWY used in their vowel role as reading facilitators (Ravid, 2001):

1. *Root letters*. While root letters are generally consonantal (Ravid, 2002), in some cases they represent vowel values. For example, one of the few cases when A appears in word-internal position is as a root letter, e.g., A in *karati* ‘(I) read’, spelled QRATY (Hebrew קראתי), root Q-R-A. All four

matres lectionis may function as vocalic root letters, and they may not be deleted when the word is pointed.

2. *Function letters*. Vowels often participate in expressing function (i.e., non-root) morphological roles, especially in word-final position. For example, Y י in *kosi* ‘my glass’, spelled KWSY (Hebrew כוסי) expresses genitive case, 1st person singular. Again, all four *matres lectionis* may function as vocalic function letters, and they may not be deleted when the word is pointed.

3. *Internal vowel letters*. W ו and Y י alone may also have an additional, in a sense less meaning-bearing role in representing word-internal *o,u,i*,[3] as part of the (mainly) vocalic pattern of the word (e.g., *o* in *gadol* ‘big’, spelled GDWL, Hebrew גדול, adjectival pattern *CaCoC*; or in *gódel* ‘size’, spelled GWDL in non-pointed script, Hebrew גודל, adjectival pattern *CóCeC*). In such cases, pointing marks may sometimes substitute for Y י and W ו, and in others they may not. This is the domain of our enquiry.

The problem of ו status

Spelling without pointing diacritics (*plene spelling*) is the default in Modern Hebrew texts intended for experienced readers, and thus requires the addition of *matres lectionis* AHWY to dispel possible ambiguity (Schwarzwald, 2001). Mature, experienced writers / readers of Hebrew usually have a firm grasp of spelling patterns of the AHWY graphemes when they function as root or function letters, since they appear in both pointed and non-pointed spelling. The representation of A

and H is the most stable among the vowel letters, since they are marked mostly in word final position and often carry morphological information which renders them particularly salient. However, there is much confusion regarding the status of W ו and Y י signifying internal vowels in the normally used non-pointed Hebrew orthography. In such cases, W ו and Y י do not convey any morphological information (in the sense of being root or function letters), and their occurrence in the word depends on whether it is pointed or not: According to the stipulations of the Hebrew Language Academy (1996) about *plene* spelling in non-pointed script, internal *o* and *u* should always be marked by W ו, and *i* should be marked by Y י in open syllables. But even mature, experienced Hebrew spellers do not follow these stipulations, and the problem of *plene* spelling is well known in Israel.

In three separate studies, Hebrew vowel spelling was found to be the most difficult category for both children and adolescents (Gillis & Ravid, 2000; Ravid & Kubi, in press; Schiff, 2001): Vowel letters were exchanged, deleted and inserted by spellers more frequently than consonant letters. Most prone to spelling errors were words with non-morphological word-internal W ו and Y י, which have two alternative spellings in Hebrew: *plene* (or non-pointed), with the vowel letter marked, and pointed, without the vowel letter.

Our study focuses on perceiving spelling patterns in words containing ו which marks *o* and *u* as function letters, signifying morphological suffixes; and as internal vowels, whose spelling is most particularly problematic and unstable. The spelling of word-internal ו interacts with the morpho-phonological structure of the word. As *u*, ו is marked[4] obligatorily in stressed syllables in both pointed and non-pointed script, but when in unstressed syllables it is marked in non-pointed script only. We term this status *inconsistent.* The word *sukά* ‘hut’ would thus be spelled SWKH in

non-pointed script (Hebrew סוכה) and SKH (Hebrew סֻכָּה) in pointed script. As *o*, marking ו is dependent on the morphological word pattern. In words with inherently final stress, ו is consistent in all syllables. Thus *gadól* 'big' and *loméd* 'studies' are always spelled GDWL (Hebrew גדול) and LWMD (Hebrew לומד) respectively. However in words which have penultimate stress, the unstressed syllable will contain ו only in non-pointed script and is termed by us *inconsistent*. Thus *gódel* 'size' will be spelled GWDL in non-pointed script (Hebrew גודל) and GDL (Hebrew גֹּדֶל) in pointed script. This means Hebrew readers encounter different written representations of the same words, governed by complex morpho-phonological criteria accessible only to linguistically tutored individuals.

The problem of vowel status in the written word has broader implications for general processing theories beyond the psycholinguistics of Hebrew spelling. In a recent paper Katz & Frost (2001) adopt the view that reading and spelling interface in their dependence on *both* graphemic and phonological information rather than on one to the exclusion of the other. They propose that spelling knowledge is thus to a certain extent a function of readers' ability to recognize spelling patterns following multiple exposures to these patterns. Consequently, readers' acceptance of certain misspellings indicates that the mental orthographic representation of specific letters, which are not critical for the reader's knowledge of the word's phonology, is initially ill- or weakly formed. According to this view, the stability of a single letter is a function of the simplicity of the grapheme-phoneme relation: A stable memory trace of a spelling pattern is the result of a simpler link between phonology and orthography, which requires less processing before a decision is made about the phonemic value of the letter. As we have shown above, the internal letter ו may have a poor internal orthographic representation in Hebrew readers due to the multiplicity

and ambiguity of cues necessary for its occurrence in the word. Thus Hebrew provides us with the unique opportunity of teasing apart phonological from orthographic representation. Specifically, our study addresses the issue of whether a single letter may have less stable orthographic encoding, which means that phonology plays a role in determining which orthographic information fails to be stored.

Marking vowels by ו: Study questions

In this paper we examine the psycholinguistic status of word-internal vowel representation by a single *matres lectionis* grapheme in pointed and non-pointed Hebrew. The grapheme ו was selected for investigation since on the one hand, it designates only two vowels (*o* and *u*) and thus represents a limited and well-defined domain; but on the other hand, it may have either consistent or inconsistent status as a function letter and in representing internal vowels, and, relatedly, it participates in a variety of morphological structures. A number of interrelated psycholinguistic questions arise in this context.

- ***ו status.*** How stable is the status of ו in written Hebrew? It is *consistent* as a function letter participating in the expression of function suffixes in both pointed and non-pointed writing: the feminine plural suffix *–ot* (e.g., *ban-ot* 'girl-s' spelled BNWT, Hebrew בנות) or the abstract suffix *–ut* (e.g., *reš-ut* 'permiss-ion', spelled RŠWT, Hebrew רשות). But it is less stable when representing a word-internal vowel, depending on the morphophonological structure of the word. Note, for example, the *o* in *bóker* 'morning', which is spelled BWQR (Hebrew בוקר) but often occurs in writing as BQR (Hebrew בקר). We predict consistent ו to be more stable than inconsistent ו, i.e., for

items with consistent ו to have shorter decision times and more accuracy than items with inconsistent status

- ***ו presence or absence.*** What happens when the grapheme ו is removed? Will the resulting written string be judged as correctly or incorrectly written by literate adults? The Hebrew Language Academy stipulates where ו may be removed and where it must be retained, but how psychologically real are these stipulations? How do they interact with ו status? Despite the official language establishment, inconsistent ו is often deleted in non-pointed script and retained in pointed script. These cases are not considered strict 'spelling errors' by literate Hebrew speakers (Ravid & Kubi, in press), who are often confused about the occurrence of W ו and Y י in written Hebrew (Gillis & Ravid, 2000). Though not similar, English words such as *neighbor*, *color* or *endeavor* (US spelling), spelled *neighbour*, *colour* and *endeavour* in British English, might be considered as an analogy. We predict easier and more efficient reading of words with ו.
- ***Morphological structure.*** Is ו perceived differently in words with linear and non-linear structure? In our study, the target letter ו designated the vowel *o* or *u* in one of the syllables of the CVCVC string (*CaCoC* /*CaCuC, CóCeC* /*CuCaC*). In linear structure, ו was consistent as a function letter in the -WT suffix (e.g., *ban<u>ot</u>* 'girls', spelled BN<u>WT</u>, Hebrew <u>בנות</u>). In non-linear root and pattern structure, ו designated an internal vowel *o* or *u*, and its status was either consistent or inconsistent, as explained above. We held constant the same syllable structure CVCVC across the two morphological structures to see if they affect Hebrew readers' judgment of ו status. We predict the interference of morphological factors in reading Hebrew words with ו.

Experiment I: Pointed

Our study was designed to find out the answers to the study questions by measuring adult readers' reaction to the presence or absence of the grapheme ו with consistent or inconsistent status in written Hebrew words with the same syllabic but different morphological structures. In the first experiment, all target words were presented with pointing marks (*nikud*).

Sample

The study sample consisted of 38 third-year undergraduate education students, all literate, monolingual speakers of Hebrew from middle-high SES background without any university-level knowledge in Hebrew linguistics.

Item selection

In order to neutralize frequency effects, and in the absence of Hebrew frequency lists, the following procedure was undertaken to select test items: 35 items were presented to 30 judges (students of education), who were asked to rank them on a scale of 1-5, from most to least frequent. Estimated frequency was calculated for each word by averaging the ratings across all 30 judges, with 95% agreement among judges. On the basis of these ratings, 24 most frequent words ranked 1 and 2 were selected for the purposes of this study (e.g., *banot* 'girls', *sulam* 'ladder'). Words were presented in their written form and were thus judged by our raters. In order to check whether the written words were matched in frequency a mean rating of frequency was built for the 12 consistent words (see structure of research instrument below) , and the same was done for the 12 inconsistent words for all 30 raters. We conducted a t-test to find out whether there is a difference in the frequency of the categories. No significant differences were found ($t(28)=1.3$, n.s. This analysis was also conducted separately on

the items with differing morphological structure (see below), and again no differences were found t(10)=1.0, n.s.

Research instrument and procedure

The research instrument constructed for the purposes of this study consisted of 24 written Hebrew bi-syllablic nouns and adjectives, all with the same syllable structure CVCVC. The 24 target vowels (*o* and *u*) were spelled by the grapheme ו pertaining to two categories. One category contained 12 words with *consistent* ו representing the vowels *o* and *u* (structured *CaCoC* / *CaCuC*), further subdivided into two types of morphological structure: (i) 6 words with the same *linear* (stem and suffix) structure (e.g., *yaf-ot* 'pretty-Fm,Pl' spelled YPWT, Hebrew יפות; *resh-ut* 'permit-ing' spelled RŠWT, Hebrew רשות); (ii) 6 words with *non-linear* (root-and-pattern) structure (e.g., *karov* 'near', root *k-r-v*, adjectival pattern *CaCoC*, spelled QRWB, Hebrew קרוב). A second category contained 12 words with *inconsistent* ו (structured *CóCeC* /*CuCaC*, e.g., *bóker* 'morning', spelled either BWQR בוקר or BQR בקר), all with *non-linear* structure.

Each of the 24 test items appeared twice in random order in two conditions - with or without ו (e.g., *karov* 'near', spelled either QRWB קרוב or *QRB קרב). Pointed words without ו were presented using the alternative diacritics *xolam xaser* and *kubuc* for ו. In the case of consistent ו, absence of ו always resulted in an illegal string (e.g., *QRB). In the case of inconsistent ו, absence of ו resulted in a legal pointed string (e.g., G_oD_eL for *gódel* 'size', Hebrew גֹּדֶל) and in an illegal non-pointed string (e.g. *GDL for *gódel* 'size', Hebrew גדל). The study paradigm is presented in Table 2.

INSERT TABLE 2 ABOUT HERE

Each of the test words first appeared on a computer screen in a sentential context to ensure clear and unambiguous comprehension. First the sentence appeared on the screen with an empty slot standing for the test word. Then the actual test item appeared on the screen in larger font below its sentential context. Study participants were asked to judge whether the written string appearing on the screen was a correctly written (i.e., legal) word in Hebrew. For a legal written string they were supposed to press Enter, clearly marked "correct"; for an illegal written string they were supposed to press the space bar, clearly marked "incorrect". Each testing session was preceded by a practice session consisting of four items representing the test categories (with / without ו; consistent / inconsistent ו), which ensured that participants understood the instructions and knew what they were supposed to do. All test items are presented in Hebrew their original form in Appendix I.

Scoring

Three independent variables were tested in this experiment: ו status (consistent / inconsistent ו), ו presence (word presented with / without ו), and morphological structure (linear / non-linear structure). Table 2 shows that when items are presented with ו, they are always legal, and when items are presented without ו, they are always illegal (marked by a star), except in the case of pointed inconsistent ו.

Participants' responses were measured by reaction time to string identification and by accuracy, i.e., number of correct responses. Reaction time was measured in milliseconds. Correct responses (i.e., responses correctly identifying a test item as either a legal or an illegal string in that context) were assigned a score of 1; incorrect responses were assigned a score of 0.

Results

Below we present the results on accuracy and reaction time in the pointed experiment.

Accuracy

A two-way ANOVA with repeated measures ו presence: 2 [ו present / ו absent] x ו status: 2 [consistent / inconsistent ו] was carried out on the correct percentage scores of the study participants. Two main effects emerged: One, an effect for ו presence ($F(1,37)=6.82$, $p<.02$): Items with ו scored higher ($M=91.1$, $SD=1.66$) than items without ו ($M=83.55$, $SD=1.31$). Another effect emerged for ו status ($F(1,37)=18.17$, $p<.001$): Items with consistent ו scored higher ($M=93.09$, $SD=0.79$) than items with inconsistent ו ($M=81.58$, $SD=2.24$). No interactions emerged.

The effect of ו-status may be confounded by the fact that all 12 inconsistent items were non-linear whereas only half of the consistent items (6) were non-linear. In order to neutralize this problem, we conducted a two-way analysis (ו status x ו presence) on the non-linear items alone. Both effects emerged again: An effect of ו presence ($F(1,37)=12.9$, $p<.002$), showing that items presented with ו scored higher; and an effect of ו status ($F(1,37)=8.15$, $p<.008$) showing that consistent items scored higher. Moreover, this time we found a close-to-significant interaction of ו presence and ו status ($F(1,37)=4.08$, $p=.051$), presented in Figure 1.

INSERT FIGURE 1 ABOUT HERE

A post-hoc Bonferonni analysis of the data in Figure 1 shows that accuracy in consistent items presented without ו reduces significantly (at the .05 level), but inconsistent items presented with and without ו score the same.

The effect of morphological structure

A further analysis was conducted on the consistent ו category taking into account items' morphological structure – linearly structured items with ו in the suffix (e.g., *ban-ot* 'girl-s') versus items with non-linear root-and-pattern structure (e.g., *gadol*, root *g-d-l*, pattern *CaCoC*). All items had the same CVCWC syllabic structure with either *o* or *u* in the second syllable. We carried out a two-way ANOVA with repeated measures: ו presence: 2 [ו present / ו absent] x morphological structure: 2 [linear / non-linear]. Two main effects emerged: One was an effect for ו presence ($F(1,37=17.73, p<.001$): Items with ו scored higher (M=98.46, SD=0.48) than items without ו (M=87.71, SD=1.48). Another main effect emerged for morphological structure: ($F(1,37=16.76, p<.002$): Linear items scored higher (M=96.26, SD=0.88) than non-linear items (M=89.91, SD=1.05). These effects were mitigated by a two-way interaction of ו presence x morphological structure ($F(1,37=22.43, p<.001$), depicted in Figure 2.

INSERT FIGURE 2 ABOUT HERE

A post-hoc Bonferroni analysis showed that the interaction derives from the fact that non-linear words without ו score significantly lower than linear words without ו and, on the one hand, and than both linear and non-linear words with ו, on the other.

Reaction time

A two-way ANOVA with repeated measures ו presence: 2 [ו present / ו absent] x ו status: 2 [consistent / inconsistent ו] was carried out on the RT scores of the participants. No effect was found for any of the study variables, and no interactions emerged. We then focused on a further analysis within the consistent ו category, which had two types of morphological structures: linear (e.g., *ban-ot* 'girl-s') and non-linear (e.g., *gadol*, root *g-d-l*, pattern *CaCoC*). We carried out a two-way

ANOVA on ו presence x morphological structure. No main effect emerged, and no interaction. This analysis was repeated on the non-linear items alone (see 2.5.1 above), with the same results.

Discussion

The study task required participants to judge whether written strings containing the grapheme ו in different contexts were spelled correctly, and measured both accuracy of decision and time to lexical decision. In the first experiment, where task words were presented with pointing, participants made fewer accuracy errors in items with consistent than inconsistent ו – showing that items with inconsistent status have less stable representations, as we predicted; and had more accuracy success in items presented with ו than items presented without ו, showing that they are not adequately familiar with the system that permits the omission of ו when the word is pointed, again as we predicted. Moreover, when non-linear items were analyzed separately, it was even clearer that Hebrew readers do not tolerate the omission of ו in consistent words, while they are unclear about ו status in inconsistent words. Note, however, that all inconsistent items are legal when pointed both with and without ו; while all consistent items are illegal even when pointed when presented without ו. We return to this issue in the general discussion (section 5.0 below).

In items with consistent ו, linear items with stem and suffix structure scored higher than non-linear items with root and pattern structure, showing that ו in the morphological role of function letter is more stable than ו in the role of internal vowel letter. In fact, items with non-linear structure presented without ו had the lowest scores, showing that adult Hebrew reader/writers are least sure about the necessity of marking the vowels *o* and *u* by graphemes when there is no morphological

information available, and do not perceive pointing as adequate in preserving the written form of the word.

The first experiment, in which task words were presented with pointing, showed that time of lexical decision was not affected by ו status, its presence, nor by the word's morphological structure.

Experiment II: Non-pointed

The second experiment was conducted on the same sample 2 weeks after the first one, using exactly the same design with the same target words. This time all target words were presented without pointing marks.

Results

Below we present the results on accuracy and reaction time in the non-pointed experiment.

Accuracy

A two-way ANOVA with repeated measures ו presence: 2 [ו present / ו absent] x ו status: 2 [consistent / inconsistent ו] was carried out on the correct percentage scores of the study participants. Two main effects emerged: One, an effect for ו presence ($F(1,37)=52.01$, $p<.001$): Items with ו scored higher ($M=94.96$, $SD=1.66$) than items without ו ($M=78.94$, $SD=1.31$). Another effect emerged for ו status ($F(1,37)=27.49$, $p<.001$): Items with consistent ו scored higher ($M=95.39$, $SD=0.79$) than items with inconsistent ו ($M=78.51$, $SD=2.24$). These effects were mitigated by a two-way interaction of ו presence x ו status ($F(1,37=25.24$, $p<.001$), depicted in Figure 3.

INSERT FIGURE 3 ABOUT HERE

A post-hoc Bonferroni analysis showed that the interaction derives from the fact that inconsistent words without ו score significantly lower (at the .05 level) than

consistent words without ו and, on the one hand, and than both inconsistent and consistent words with ו, on the other.

As in 2.5.1 above, the effect of ו-status may be confounded by the fact that all 12 inconsistent items were non-linear whereas only half of the consistent items (6) were non-linear. To neutralize this problem, we conducted a separate two-way analysis (ו status x ו presence) on the non-pointed non-linear items. Both effects emerged again: An effect of ו presence ($F(1,37)=40.74$, $p<.001$); and an effect of ו status ($F(1,37)=25.59$, $p<.001$). We also found exactly the same interaction of ו presence and ו status ($F(1,37)=24.45$, $p=<001$), with almost identical values (Consistent, ו present, M=99.12, SD=3.7; Consistent, ו absent, M=90.35, SD=14.3; Inconsistent, ו present, M=91.23, SD=19.1; Inconsistent, ו absent, M=65.79, SD=28.1). This points to the robustness of our results.

The effect of morphological structure

A further analysis of accuracy was again conducted on the consistent ו category taking into account items' morphological structure – linearly structured items with ו in the suffix (e.g., *ban-ot* 'girl-s') versus items with non-linear root-and-pattern structure (e.g., *gadol*, root *g-d-l*, pattern *CaCoC*). Morphology items – like all task items – had the same level of frequency, and did not differ from each other in degree of homography. All items had the same CVCWC syllabic structure with either *o* or *u* in the second syllable. We carried out a two-way ANOVA with repeated measures: ו presence: 2 [ו present / ו absent] x morphological structure: 2 [linear / non-linear]. One main effect emerged for ו presence ($F(1,37=16.13$, $p<.001$): Items with ו scored higher (M=98.68, SD=0.48) than items without ו (M=92.11, SD=1.48). There were no other main effects and no interactions.

Reaction time

A two-way ANOVA with repeated measures ו presence: 2 [ו present / ו absent] x ו status: 2 [consistent / inconsistent ו] was carried out on the RT scores of the participants. No effect was found for any of the study variables, and no interactions emerged. This analysis was repeated on the non-linear items alone (see 2.5.1 above), with the same results. We then focused on a further analysis within the consistent ו category, which had two types of morphological structures: linear (e.g., *ban-ot* 'girl-s') and non-linear (e.g., *gadol*, root *g-d-l*, pattern *CaCoC*). We carried out a two-way ANOVA on ו presence x morphological structure. No main effect emerged, but there was a significant interaction ($F(1,37)=5.68$, $p<.03$), depicted in Figure 4. The post-hoc Bonferroni analysis could not find the source of the interaction, but Figure 4 shows that the items that had the fastest RT were non-linear and presented without ו.

INSERT FIGURE 4 ABOUT HERE

The problem of homography

Due to the under-representation of vowels in unpointed Hebrew script, many written strings are homographic with other written strings, so that test items without ו may be legal strings even when the obligatory ו is omitted. Therefore we have conducted an analysis of homography in our test items (see list in Appendix II). Note, first, that

23 out of 24 non-pointed words presented without ו are homographic with some other written string in Hebrew, so are in fact, in a sense, 'legal' words. In Appendix II we scored the 24 words for a likelihood of being 'legal' or homographic without ו on a scale of 1-4: 1- most probably a legal string; 2- a possible legal string; 3- just possibly a legal string; 4 – impossible as a legal string. The words are presented in Hebrew. Out of the 24 non-pointed strings without ו, 13 are most probably legal words, 5 are possible, 4 are just possible, and one (שטת) cannot be interpreted as a possible legal

string. A one-way analysis by homography type (1,2,3) showed no significant effect of homography (F(2,74)=1.51, n.s): Type 1 M=0.90, SD=0.12; Type 2: M=0.89, SD=0.18; Type 3: M=0.93, SD=0.14. No interactions emerged.

Discussion

In the second experiment, the same task items were presented in non-pointed form. As in the previous experiment, consistent items and items with ו had higher accuracy scores. Inconsistent items presented without ו had the lowest scores, and this shows that the locus of the problem of written vowel representation in Hebrew is in the inconsistent ו class. The same results emerged when non-linear items were analyzed separately. In this non-pointed condition, the fastest lexical decisions were made on non-linear items without ו. Our interpretation is that this result derives from the fact that such items constitute non-pointed trilateral written strings (e.g., GDL to be read as *gódel* 'size'), which take the form of consonantal roots. Since roots have a unique status in the Hebrew lexicon, these were perceived as units faster than other words containing marking which required more time for lexical decision.

General discussion

The study examined adult Hebrew reader / writers' perception of the status of the grapheme ו standing for the vowels *o* and *u*, given the complex morpho-phonological and morphological contexts for its occurrence in the word. Our findings lead us to a number of conclusions.

ו status and ו presence

We hypothesized that ו might not be perceived uniformly in written Hebrew. The variable *ו status* had two alternatives: Consistent and inconsistent status. Consistent ו items consisted of two types of items: Non-linear words where ו marks the internal vowels of the pattern (e.g., GDWL *gadol* 'big', Hebrew גדול, pattern

CaCoC; KTWB *katuv* ‘written’, Hebrew כתוב, pattern *CaCuC*); and linear words, where the ו is part of the feminine plural suffix *–ot* or abstract suffix *–ut*, both spelled -WT (e.g., BNWT *banot* ‘girls’, Hebrew בנות; RŠWT *rešut*. ‘permission’, Hebrew רשות). In both cases, ו is consistent across the board. Inconsistent ו items were all non-linear words with *o* or *u*, with inconsistent ו deleted in pointed script and retained in non-pointed script (e.g., G(W)DL *gódel* ‘size’, Hebrew ג(ו)דל, pattern *CóCeC* ; Š(W)TP *šutaf* ‘partner’, Hebrew ש(ו)תף, pattern *CuCaC*).

Our results provide evidence in support of the claim that ו status is indeed non-uniform in written Hebrew; Adult readers find it easier to correctly identify words with consistent ו than words with inconsistent ו both overall and specifically in the non-linear category. This effect is robust and does not change with pointing; Consistent ו items were identified correctly more often than inconsistent items even when both categories were pointed and with ו.

Note that this finding covers the correct identification of both correctly and incorrectly written strings. Consistent words are always written with ו – and in half of them, ו is a function letter carrying important morphological information. The inconsistent words, in contrast, sometimes show up with ו and sometimes, when pointed, show up without ו. Therefore, it is easy to identify a consistent ו word as either correctly written with the ו or incorrectly written without the ו; however making the same decision about inconsistent words is not as clear-cut, and requires paying additional attention to whether the word is also pointed (and then correct), or non-pointed (and then incorrect). Inconsistent ו placement thus does not have a stable representation in mature, literate Hebrew readers. Our conclusion is that consistent ו is more robust and stable than inconsistent ו.

Our findings confirm the weak or unstable status of Hebrew words with inconsistent ו that has long been observed by linguists (Schwarzwald, 1995). The category with the lowest correct scores was inconsistent ו without ו in the non-pointed condition: A third of the responses on incorrect strings such as *MKR for *mukar* ‘familiar’ (Hebrew מכר) identified it as correct. While spelling errors in homophonous graphemes disappear from written Hebrew at the end of gradeschool, such no-ו renderings of words with inconsistent internal ו frequently occur in the writing of adolescents and educated (though non-expert) adults. Ravid and Kubi (in press) found that omission and redundant marking of internal Y י and W ו are the most frequently occurring error category in the Hebrew writing of children, adolescents and adults. In this context, and given the current results, we would like to make a distinction between *an incorrect* representation in Hebrew due to substitution or to omission of consistent ו, which results in an *unacceptable* written string (e.g., *YPT for *yafot* ‘pretty,FmPl’, Hebrew יפת); and an *unstable* representation due to omission of ו in non-pointed inconsistent ו words, which results in a *less acceptable* string (e.g., ?GDL for *gódel* ‘size’, Hebrew גדל). The former is considered a spelling error by all literate speakers, the latter is not.

These results provide independent evidence for the reading / spelling processing model proposed in Katz & Frost (2001), which claims that internal orthographic representations of words are increasingly strengthened with each exposure during reading, but not all graphemes are strengthened equally. Results of their four experiments indicate that subjects have poor internal orthographic representations for letters which have multivalent relationships with the spoken form. Like English geminates and schwas, Hebrew *matres lectionis*, and ו specifically, have a more ambiguous relation to speech than graphemes which code consonants, for

example, and are thus coded less effectively. Overall evidence from Hebrew shows indeed that these ambiguous letters are orthographically represented last and the weakest. In line with the neuro-linguistic functional magnetic resonance imaging study discussed in Pugh et al. (2000), we show that while making a decision on the correct spelling of the vowels *u* and *o*, both spellings are activated and compete with each other, and therefore fail to strengthen the correct spelling and create a deep memory trace of its pattern.

Morphological distinctions

Hebrew, however, is a language with rich morphological, in addition to phonological and orthographic, information conveyed in the spelling system. Our study also provides support to the morphological hypothesis presented in 1.1 above, in two different ways. First, there is clear evidence that Hebrew readers integrate the linear / non-linear structure distinction into their reading strategies. In the consistent ו category, words with linear structure were identified correctly more often than items with non-linear structure. Recall that in this category, removing the ו always results in an incorrect string, while retaining it is always correct. If morphology were not an issue, we would get the same results for both structure types. The actual results indicate that it is easier to identify a linear than a non-linear written string with or without ו. This is because, as we saw above, ו constitutes an essential part of the suffix –WT as a function letter with a clear morphological role (*-ot* for plural feminine or –*ut* for abstract nominal), and together WT form a separate morphemic unit which is easily identified by Hebrew speakers (Ravid, 2001). ו presence is therefore critical in linear structure and its removal breaks apart the meaningful morpheme. It might be argued that since this is the consistent ו category, ו presence should be crucial in non-linear structure as well. But as explained above, ו does not carry a typical

morphological role in representing an internal vowel: the larger unit it forms part of is the pattern, an abstract discontinuous unit which is hard to identify, isolate and represent by Hebrew speakers (Ravid & Malenky, 2001). Moreover, other vowels in this pattern (*a*,*e*) are marked by zero as a rule (Table 1). The removal of ו – the only overt written symbol of the pattern - in consistent structure is thus still perceived as incorrect, but identification lags behind linear structure.

There is another interesting angle to our morphological findings, which goes beyond the linear/non-linear distinction. Our results provide support for the psycholinguistic reality of the Hebrew root in a number of ways. First, in the consistent ו category, items with non-linear root-and-pattern structure and without ו are identified faster without pointing. Such items are (incorrectly) represented in written Hebrew in a sequence of three graphemes, all standing for consonants, e.g., GDL 'size', KTB 'write' - in other words, root-like strings. Such a vocalically "neutral" root-like string is immediately recognized as a possible written word in Hebrew, since the most basic and frequent verb pattern as well as two basic and frequent noun patterns in Hebrew are spelled as three-letter vowel-less strings in non-pointed script. Hebrew readers frequently encounter such "neutral" root-like strings and attribute one of the possible vowel patterns to them. The omission of pointing in this case makes for faster recognition of the basic lexical unit in Hebrew. Moreover, among consistent ו test items without ו, items with non-linear structure (both pointed and non-pointed) are identified faster than those with linear structure. The items identified faster have a root-like structure – since, indeed, what is overtly represented after the omission of the ו is the bare root. The linear items without W ו end with T ת, a typically function (non-root) letter signifying a variety of inflectional and

derivational morphemes (Ravid, 1995, 2001), and this non-root-like sequence seems to take more time to process than root-like strings.

Conclusion

This study presents initial results on representation of the vowels *o, u* in Hebrew by the grapheme ו in words with different morphological structures within both pointed and non-pointed systems. The study focused on the Hebrew grapheme ו in the role of marking internal vowels and as a function letter and showed that ו status is non-uniform. The analysis of the status of this vowel letter in Hebrew provides a window on two issues. One is the relationship between orthographic and phonological representation while making spelling decisions: Our study was able to isolate the orthographic representation of words with internal *o, u* from its phonological representation and to show that they are not linked in a straightforward manner.

A second issue is the general question of how spelling patterns are learned. Our results provide some support for the *resonance model* (Stone & Van Orden, 1994), a general theory for learning the relations between spelling and speech. According to this model, the covariance of orthographic and phonological events while recognizing spelling patterns is the main mechanism for strengthening the connections between those representations (Katz & Frost, 2001). The Hebrew-specific case shows that inconsistent words misspelled without ו are phonological acceptable, and thus the connection between ו-absent spelling and its phonological representation is strengthened, with the result that such spelling becomes more acceptable. The general implication is that the ambiguities that exist in the relationships between orthography, phonology and morphology underlie spelling knowledge.

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Table 1. AHWY (Hebrew אהוי) in their dual function as consonant and vowel designators

Grapheme	**Hebrew form**	**Consonant**	**Vowel**	**Constraints on occurrence as vowel designator**
A *Alef*	א	*?*	*a,e*	Word final (unless root letter)
H *He*	ה	*h*	*a,e*	Word final
W *Vav*	ו	*v* (historically, *w*)	*o,u*	No constraints
Y *Yod*	י	*y*	*i*	No constraints

Table 2. Task structure and structure of the test categories, with examples

	12 items with Consistent ו		12 items with Inconsistent ו
ו present (24 items)	6 <u>Non-linear structure</u> • *karov* KRWB ‘near’ Root *k-r-v*, Pattern *CaCoC* • *katuv* KTWB ‘written’ Root *k-t-b*, Pattern *CaCuC*	6 <u>Linear structure</u> • *yaf-ot* YPWT ‘pretty-,Fm,Pl’ • *reš-ut* RŠWT ‘permiss-ion’	<u>All non-linear structure</u> • *bóker* ‘morning’ BWQR Root *b-k-r*, Pattern *CóCeC* • *šutaf* ‘partner’ ŠWTP Root *š-t-f*, Pattern *CuCaC*
	12 items with *Consistent ו		12 items with Inconsistent ו
ו absent (24 items)	6 <u>Non-linear structure</u> • *karov* *KRB ‘near’ Root *k-r-v*, Pattern *CaCoC* • *katuv* *KTB ‘written’ Root *k-t-b*, Pattern *CaCuC*	6 <u>Linear structure</u> • *yaf-ot* *YPT ‘pretty-,Fm,Pl’ • *reš-ut* *RŠT ‘permiss-ion’	<u>All non-linear structure</u> • *bóker* ‘winter’ BQR Root *b-k-r*, Pattern *CóCeC* • *šutaf* ‘partner’ ŠTP Root *š-t-f*, Pattern *CuCaC*

Figure 1. Experiment 1, Accuracy scores (pointed items): Interaction of ו presence (+ ו / - ו) x ו status (consistent / inconsistent)

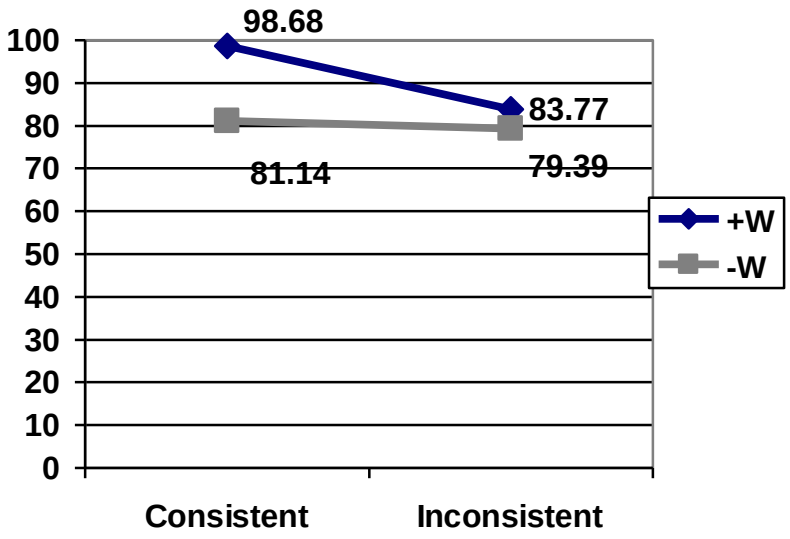


Figure 2. Experiment 1, Accuracy scores (pointed items): Interaction of ו presence (+ ו / - ו) x morphological structure (linear / non-linear) in consistent ו items.

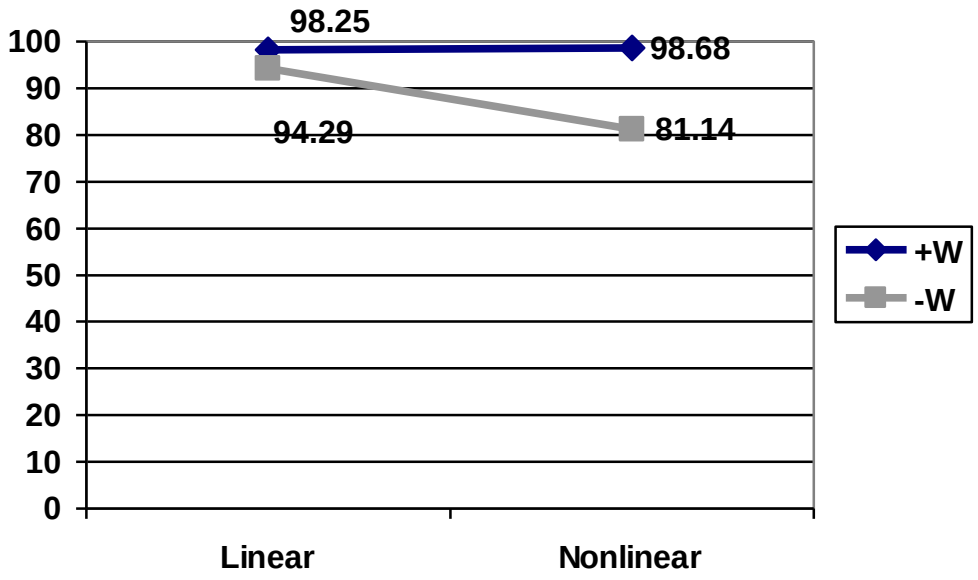


Figure 3. Experiment 2 (non-pointed items): Accuracy scores: Interaction of ו presence (+ ו / - ו) x ו status (consistent / inconsistent).

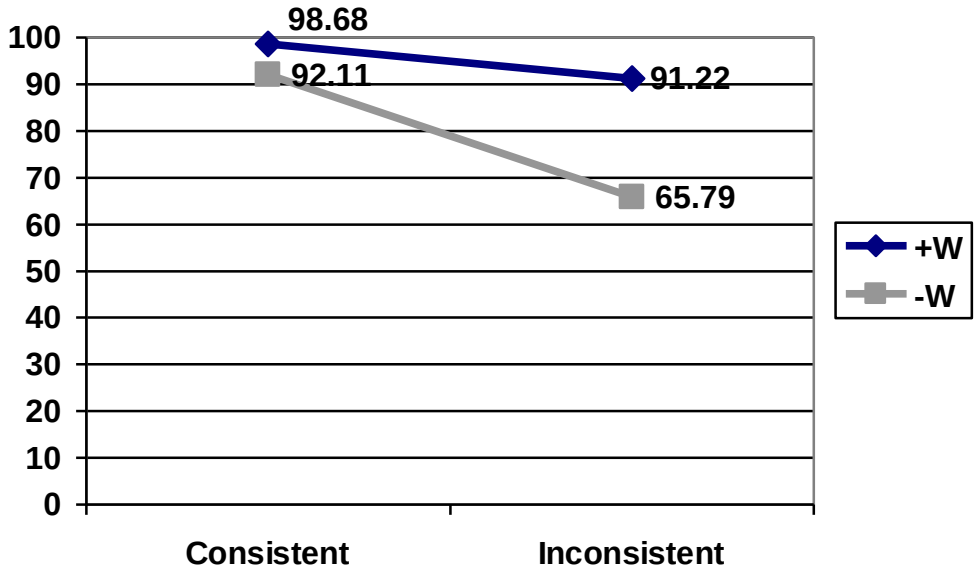
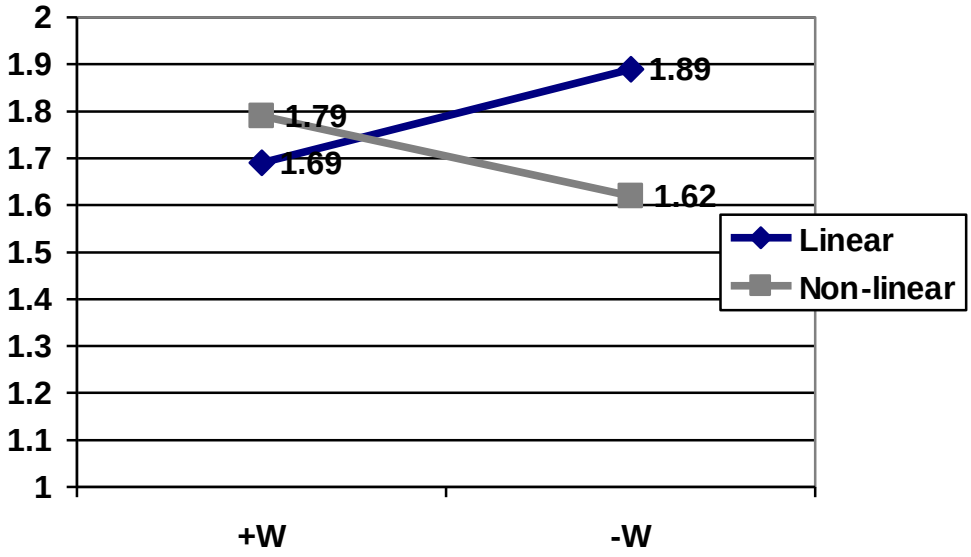


Figure 4. Experiment 2, Reaction time (non-pointed): Interaction of ו presence (+ ו / - ו) and morphological structure (linear / non-linear) in consistent ו items



Appendix I

List of all task words as presented in Hebrew in Experiment (non- pointed)		List of all task words as presented in Hebrew in Experiment (pointed)	
W absence	**(ii) W presence**	**(ii) W absence**	**(i) W presence**
בנת	בנות	בָּנֹת	בָּנוֹת
טובת	טובות	טוֹבֹת	טוֹבוֹת
חלת	חלות	חַלֹּת	חַלּוֹת
טעת	טעות	טָעֵת	טָעוּת
שטת	שטות	שְׁטֵת	שְׁטוּת
רשת	רשות	רְשֵׁת	רְשׁוּת
קרב	קרוב	קָרֹב	קָרוֹב
רחק	רחוק	רָחֹק	רָחוֹק
גדל	גדול	גָּדֹל	גָּדוֹל
עסק	עסוק	עָסֵק	עָסוּק
כתב	כתוב	כָּתֵב	כָּתוּב
סגר	סגור	סָגֵר	סָגוּר
אכל	אוכל	אֹכֵל	אוֹכֵל
ארך	אורך	אֹרֵךְ	אוֹרֵךְ
חרף	חורף	חֹרֶף	חוֹרֶף
בקר	בוקר	בֹּקֶר	בּוֹקֶר
גבה	גובה	גֹּבַהּ	גּוֹבַהּ
רחב	רוחב	רֹחַב	רוֹחַב
קפה	קופה	קֵפֶה	קוּפָּה
סכה	סוכה	סֵכָּה	סוּכָּה
סכר	סוכר	סֵכָּר	סוּכָּר
מכר	מוכר	מֵכָּר	מוּכָּר
סלם	סולם	סֵלָּם	סוּלָּם
שתף	שותף	שֵׁתֶף	שׁוּתָּף

Appendix II. Analysis of homography in non-pointed test items

Non-pointed task words presented without ו	**Possible legal word**	**Score as legal word** 1-most probably 2-possible 3- just possible 4- impossible
Consistent - linear		
בנת	*bant* 'you, Fm. Understood'	3
טובת	*tovat* 'welfare, bound compound form'	2
חלת	*xalat* 'sweet bread, bound compound form'	2
טעת	*ta'at* 'planting, non-finite form' (*la-* 'to' missing)	3
שטת	impossible	4
רשת	*réšet* 'net'	1
Consistent - nonlinear		
קרב	*karav* 'come closer'	1
רחק	*raxak* 'go further away'	1
גדל	*gadal* 'grow up'	1
עסק	*asak* 'be occupied'	1
כתב	*katav* 'write'	1
סגר	*sagar* 'shut'	1
Inconsistent - linear		
אכל	*axal* 'eat'	1
ארך	*arax* 'last, V'	1
גבה	*gava* 'become tall' / collect money'	1
רחב	*raxav* 'wide'	1
חרף	*xaraf* 'spend the winter'	2
בקר	*bakar* 'cattle'	2
קפה	*kafe* 'coffee'	1
סכה	*sika* 'pin'	2
מכר	*makar* 'acquaintance'	1
סלם	*salam* 'their basket'	3
סכר	*saxar* 'dam, V'	2
שתף	*šitef* 'share'	3

[1] We have chosen to represent Hebrew letters by their capital Latin counterparts, and pointing marks by subscript Latin vowel letters.
[2] Root radicals are marked by C's.
[3] A may also appear word-internally in words of foreign origin, e.g., *bar* 'bar' spelled BAR, Hebrew באר (compare with *bar* 'wheat' spelled BR, Hebrew בר).
[4] The following description relates to uninflected words only.