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Morphological density and reading comprehension in Hebrew novice readers

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Abstract

Hebrew allows the representation of the meaning of a few words in one dense form by using bound morphemes that linearly attach to the word. By manipulating words' density in text, that is, decomposing them into isolated words which changes the length of the text, it was possible to check the impact of density on reading comprehension in novice readers. Each of the 292 s graders from a low SES background, of whom 79 were struggling readers (poor decoders) and the rest were typical readers, were tested in two reading comprehension tests: dense and decomposed. They also were tested in other literacy measures (word recognition, decoding, morphological awareness, vocabulary, and spelling) to learn about their reading proficiency and awareness of morphemes. The results showed a significant interaction between text type and reading ability group, while controlling for vocabulary, indicating that text density levels had varying effects on reading performance in each reading ability group. This interaction manifested as typical readers benefiting more from decomposed texts, evidenced by improved comprehension scores for these texts compared to dense texts. In contrast, struggling readers' comprehension scores did not significantly differ between the two text types, suggesting that text density did not influence their reading performance to the same extent. Furthermore, typical readers exhibited better performance across all literacy measures, including morphological awareness. Findings suggest that a certain level of phonological decoding and morphological awareness are needed to benefit from decomposed texts. Morphological density adds another layer of difficulty for novice readers, who need to unfold the word's structure and reveal the full meaning – a process that is assumed to be cognitively complex. They also highlight the importance of morpheme awareness in dense, morphologically complex languages like Hebrew at an early age.

Keywords Morphological awareness · Morphological density · Reading comprehension · Word recognition · Hebrew · Second graders

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Literature overview

Hebrew tends to use morphologically complex and dense forms by using long clusters of bound morphemes that are attached linearly to a word. The Hebrew single word, *k'sh'erehu*, for example, is equivalent to the four separate words in English: "when I [will] see him". One dense word in Hebrew might represent the information of an entire phrase in English. Such words, which often appear in written texts and are rarer in everyday speech, have dense structures that are assumed to involve a decomposition process. This complexity can slow down their recognition, posing a significant challenge in reading comprehension (Navon & Shimron, 1985; Shimron, 2006; Vaknin-Nusbaum & Raveh, 2019; Vaknin-Nusbaum & Sarid, 2021). Additionally, this morphological complexity may pose even greater challenges for children from low SES backgrounds, who often have underdeveloped morphological awareness and vocabulary. This can impede their ability to comprehend dense morphological structures effectively (Apel et al., 2013; Colé et al., 2018).

According to Dual-route models, less familiar and morphologically complex forms are assumed to be recognized by the morphological route, in which written words are decomposed into sub-units (morphemes) to access their representation and meaning. The whole word access route develops over time with accumulated experience and exposure to print and complex forms (See, for example, dual route morphological models for reading; Baayen et al., 1997; Chialant & Caramazza, 1995; Shimron, 2006; Vaknin & Shimron, 2011).

Novice readers are still in the process of establishing sub-lexical morphemic mental representations (the smallest units of meaning) and understanding how they are combined to form specific words. These morphological features are represented alongside other essential linguistic aspects (such as phonological, semantic, syntactic, and orthographic) that determine the quality of mental representations (Perfetti et al., 2008; Perfetti & Stafura, 2014). Which is integral to word knowledge, is crucial for effective reading comprehension. This understanding enables readers not only to recognize words but also to make inferences from the text—a process that involves integrating meanings to construct a coherent mental model of the text. This skill, strongly linked to morphological awareness, becomes particularly crucial in dealing with complex language structures (Geva & Massey-Garrison, 2013; Lesaux et al., 2006; Smith et al., 2021). However, there is considerable variation among readers in the quality of their mental representations and, consequently, in their ability to decompose both familiar and unfamiliar words into their constituent morphemes. As morphemes serve as bridges to meaning in both spoken and written language, a deficit in morphological knowledge is reflected in reading performance at both word and text levels (Carlisle, 2010; Carlisle & Fleming, 2003; Goodwin et al., 2017, 2019). This can be critical, particularly in languages with complex morphology such as Hebrew – the language investigated here. However, despite its morphological complexity, Hebrew's inflection system, primarily possessive inflections, can be manipulated by replacing bound morphemes with words that convey the same meaning (like "my", "their", "her" etc.). As a result, the number of words in a text increase and the level of morphological complexity is reduced. In terms of reading comprehension, such manipulation can benefit novice readers in general and struggling readers in

particular. This study aims to examine the impact of manipulating text density on the reading comprehension performance of Hebrew-speaking students from low SES backgrounds, at the beginning of second grade, while accounting for their vocabulary knowledge. Results might suggest educational implications for the use of dense forms in texts for novice readers from low SES environment.

The role of morphological awareness in reading

According to the "lexical quality hypothesis", the process of reading comprehension is influenced by the depth of linguistic attributes attached to word mental representations. Morphology plays a central role in this process (Perfetti et al., 2008; Perfetti & Stafura, 2014). Given the connection between morphological structures and linguistic attributes, readers' ability to intentionally analyze, decompose, and manipulate words into their morphemes (e.g., root, affixes, etc.) becomes indispensable. This skill is termed morphological awareness (MA) (Carlisle & Fleming, 2003; Carlisle, 2010). Theoretical models suggest that students can benefit from such awareness during reading. This is because morphemes convey semantic, grammatical, and syntactical meanings that are crucial to word and text comprehension (Carlisle, 2003; Goodwin & Ahn, 2010, 2013; Perfetti & Stafura, 2014; Frost, 2012). Decomposing morphologically dense or complex words into their components might assist novice readers in coping with unfamiliar forms less used in everyday spoken language (Carlisle, 2010). This can be challenging for children from low SES backgrounds, who face unique challenges in developing MA. These challenges often correlate with poor vocabulary knowledge, impacting their reading comprehension and overall literacy development (Apel et al., 2013; Colé et al., 2018; Rassel et al., 2021; Sparks & Deacon, 2015). Such challenges are further compounded by the complexities of morphologically rich languages like Hebrew.

Unpacking morphological density through decomposition

According to dual-route models, this decomposing process can be accomplished by relying on the morphological decomposition route. In this route, written words are decomposed into sub-units to access their representation and meaning, as evidenced in works by Baayen et al. (1997), Chialant and Caramazza (1995), Shimron (2006), and Vaknin & Shimron (2011). Recent studies extend this understanding by highlighting that skilled reading, especially in complex morphologies, involves rapid recognition and segmentation of words into constituent morphemes, a process termed 'morpho-orthographic segmentation'. This ability, crucial in navigating morphologically complex languages, has been shown to develop over time, becoming more pronounced in adolescence (Dawson et al., 2021).

This decomposition can be especially challenging for novice readers. Seymour (2006) posits that such a procedure can be employed by novice readers only after the milestones of reading have been established. Students then can shift their attention to word morphemes during reading, at the morphographic stage, post-acquiring spelling relations and building internal orthographic unit representations.

Another perspective, offered by Frost (2012) and Share (2018), proposes that novice readers construct morphemic representations alongside reading acquisition. They utilize all linguistic information available attached to a word throughout reading to derive meaning. However, one should also consider variations among readers. Some novice readers might leverage their morphemic awareness during reading acquisition for comprehension, while others might apply their morphemic knowledge after achieving a certain reading proficiency level and consolidating their morphographic representation storage (Vaknin-Nusbaum & Sarid, 2021).

All in all, it can be concluded that due to their morphological complexity, dense words are more challenging to read for novice readers as opposed to words that convey a simpler structure. The cognitive effort invested in the process of reading such words also depends on the quality of readers' mental representations and their level of reading – in particular during the first elementary school years in which reading acquisition takes place. In this context, understanding the process by which children acquire and represent morphological knowledge to support this processing emerges as a complementary area of interest. Further exploration in this domain could provide valuable insights on how such knowledge influences reading comprehension, particularly in contexts where dense morphological structures are prevalent (Dawson et al., 2021).

Hebrew morphology

Hebrew uses both non-linear and linear formations. Non-linear formation in Hebrew is primarily used to produce derivations by interweaving a consonantal root morpheme into a phonological pattern, which is usually composed of vowels and, in some cases, also contains consonants. The word '*mashpex*' (meaning 'funnel') is formed by interweaving the three-consonant root SH.P.X into the pattern MaCCeC (where C stands for the root letters representing a consonant). While the root serves as the core of the word, pointing to a family of words constructed from the same morphemic root, the final meaning of the word is provided by the phonological pattern. That is, implementing the same root into different patterns results in a different meaning. This also means that almost every word in Hebrew consists of at least two morphemes: a root and a pattern (Ravid, 2006; Shimron, 2006).

However, linear formation in Hebrew, like English and other European languages, is achieved by the attachment of morphemes to the beginning or the end of a word. To create the plural inflection *gamadim* 'dwarves', one should attach the masculine plural suffix -im to the word *gamad* 'dwarf'. Similarly, the possessive inflection *tiki* 'my backpack' is created by attaching the possessive suffix -i to the word *tik* 'backpack'. Whereas plural inflections are frequent, obligatory, and are relatively acquired easily throughout childhood (with the exception of irregulars) (Ravid, 1995; Ravid et al., 2008), possessive inflections are not as common in everyday speech and are considered non-obligatory. They require sensitivity to the gender, number, and person of the inflection (Schiff et al., 2011) - information that is concealed in one word. Thus, it might not be surprising that awareness of their structure is found to be correlated to reading comprehension in novice readers (Vaknin-Nusbaum et al., 2016a).

Similarly, Hebrew allows for the linear attachment of several bound morphemes to one word, resulting in a dense form that conceals the meaning of a phrase. To understand the dense word *a'sh'marehu* "I will keep him safe," the reader needs to decompose it into four morphemes, find each meaning, and integrate them into a whole. This process is assumed to influence reading comprehension and points to the important role of morphological aspects in words' mental representations among Hebrew readers (Shimron, 2006) (For further introduction to Hebrew morphology, see also Schwarzwald, 2000, 2001).

Since such linear formation is not obligatory (Schwarzwald, 2002; Shimron, 2006) but often appears in written texts, including those of young children in preschool and kindergarten (Nevo et al., 2023), the manipulation of word density can shed light on MA reading relationships among novice readers with different reading levels. That is, breaking each non-obligatory dense word, linearly formed, into its linguistic components – creates a meaning-comparable phrase that is morphologically simpler yet longer in terms of the number of words. The effect of such manipulation on reading comprehension of novice readers was tested in the current study in pointed Hebrew – a transparent orthography. Previous studies, though focused on different types of morphological complexity, have demonstrated that reducing morphological complexity can facilitate word processing (Frost, 2006; Frost et al., 2005). This principle is relevant in the context of dense forms (like *a'sh'marehu*), which pose a unique morphological challenge. Simplifying these structures is thus hypothesized to aid in enhancing reading comprehension, especially for novice readers.

Hebrew orthography

Children learn to read in a transparent, also known as pointed or voweled, orthography during the first and second grades. In this system, consonants are represented by letters and vowels by diacritics that usually appear below or above the letters. These diacritics are gradually omitted from the writing system during third grade, as children transition to reading in an unpointed orthography. Thus, unlike English, which is considered deep due to its inconsistency (irregularity) in letter-sound correspondence, Hebrew's unpointed orthography is deemed deep due to the absence of vowel representation in the writing system. Orthographic depth seems to be related to the ease or challenges of learning to read (e.g., Frost, 2006, 2009). Learning to read in pointed Hebrew appears to be a simpler task compared to languages with deep orthographies like English. However, achieving profound reading comprehension relies not only on the ease of phonological decoding but also on an awareness of a word's morphological structure. Indeed, awareness of both inflectional and derivational morphology has been shown to predict reading comprehension in second-grade Hebrew readers (Vaknin-Nusbaum & Sarid, 2021; Vaknin-Nusbaum et al., 2016b). This awareness can be even more crucial when transitioning to an unpointed orthography in the later elementary school years. Children can compensate for the missing phonological information in unpointed texts by using the morphological attributes of words, aiding in accessing their representation and meaning (Vaknin-Nusbaum, 2018, 2021; Vaknin–Nusbaum & Raveh, 2019). Frequent exposure to morphologically complex words during reading can also enhance children's structural awareness

of words (Verhoeven & Perfetti, 2011) as well as the level of morphological transparency in print (Ravid & Malenky, 2001; Ravid & Schiff, 2006). Considering the unique features of Hebrew morphology and the gradual development of morphemes' mental representations among novice readers, it's plausible that words with complex morphology might be more challenging to understand due to the combined processes of morphological decomposition and phonological decoding.

Although the current study primarily focused on pointed Hebrew, due to the participants being at the initial stages of reading development, it is plausible that the complexities of morphological structures and their impacts on reading comprehension could also apply to unpointed Hebrew. Frost (2006) and Frost et al. (2005) have demonstrated that reducing morphological complexity facilitates the processing of word recognition. While these studies focused on isolated words, it is likely that the principle of reduced morphological complexity facilitating word recognition extends to the broader context of reading comprehension, particularly for novice readers.

The current study

Hebrew, the language under investigation, is notable for its complex and dense morphology. Forms such as bound morphemes used for possessive inflections often appear in texts but are less common in speech. Importantly, the use of bound morphemes, such as in possessive inflections, is not obligatory. As a result, a linearly constructed dense word comprising bound morphemes can be deconstructed into a series of words (two or more). This process provides an opportunity to manipulate the morphological density in texts. Though previous studies, such as Vaknin-Nusbaum and Sarid (2021), have underscored the significance of MA in reading comprehension among Hebrew readers, the influence of text density on comprehension in novice readers remains less investigated.

The effect of manipulating text density was previously examined in a study by Asadi and colleagues (2024) involving fifth-grade Arabic readers. Their findings revealed a density effect exclusively among students with reading disabilities, with improved performance noted in comprehension tests using decomposed text. However, Asadi's study did not assess MA and vocabulary knowledge, which challenges the ability to draw definitive conclusions from their results Furthermore, given that fifth graders are often proficient readers, the results from Asadi's study may not be directly applicable to novice readers. Additionally, the difference in spoken and written Arabic compared to Hebrew poses challenges in transferring these findings to other Semitic languages.

As suggested by Navon and Shimron (1985), greater consideration should be directed towards reading to the way in which multi-affixed words are decoded because their dense structure might impact reading proficiency (Shimron & Sivan, 1994). This study, therefore, aims to fill a gap in the literature by exploring the impact of text density on novice Hebrew readers, particularly focusing on children from low SES backgrounds. Such children are often at greater risk of literacy challenges due to limited vocabulary and morphological awareness (Apel et al., 2013; Colé et al., 2018; Rassel et al., 2021; Sparks & Deacon, 2015). The findings from this study are expected to shed light on the educational implications of using dense words in texts

for both typical and struggling readers from low SES backgrounds. To achieve these objectives, the study posed the following research questions:

1. How do MA (inflectional and derivational) associate with reading comprehension of the two types of texts (dense/decomposed) within both reading ability groups (typical/struggling)?
2. What are the mutual effects of text type (dense/decomposed) and reading ability group?

Method

Participants

A total of 292 s-grade native Hebrew-speaking students participated in the study, including 133 boys and 159 girls, aged 7–8 years ($M=7.51$, $SD=0.39$). These participants were selected from 10 s-grade classes in four public schools. The gender distribution was consistent across schools ($\chi 2=5.6$, $p=.13$).

The schools are located in a town of low socioeconomic status in northern Israel. The town ranks 94 out of 255 in terms of overall socioeconomic status according to the Central Bureau of Statistics (2019). According to the state's nurture decile index for schools, 11 out of 12 Hebrew-speaking schools in the city are rated within a nurture index range of 7 to 9 (Meida La'am, 2017). The criteria for the nurture index include academic achievements (accounting for 20% of the score), the socioeconomic status of the students' families (40%), school infrastructure and resources (20%), and the level of parental involvement and community support (20%). The evaluation is based on a comprehensive assessment that includes both qualitative and quantitative measures, aiming to provide a holistic view of the school's educational environment. The calculation of the nurture index is conducted in two stages. First, an assessment of the school's academic achievements is made, based on standardized test scores and other academic performance indicators. In the second stage, the socioeconomic status of the students' families is evaluated based on various demographic and economic factors (Yellink, 2023). This index is categorized from 1 to 10, where a lower number indicates a higher socioeconomic status and a reduced need for supplemental support from educational authorities. Conversely, a higher number indicates a lower socioeconomic status, reflecting greater needs for assistance (Meida La'am, 2017; Yellink, 2023). The schools in this study fall within a nurture index range of 8 to 9 (Meida La'am, 2017). According to information provided by homeroom teachers, who were asked to supply the researchers with a list of students and specifically report any known language, attention, or developmental deficits. Students with potential deficits were excluded based on teacher reports. Thus, no specific deficits were noted among the children in the study.

The participants in this study were categorized into two groups based on their performance in a phonological decoding standardized test (Shatil et al., 2007), administered at the beginning of the second grade. The test involved decoding homo-

phonic pseudowords—letter sequences that sound like real words when phonetically decoded, but do not exist orthographically. Among these participants, 79 (27%) were identified as struggling readers (poor decoders), scoring below seven out of a maximum of 22 (between 7 and 8 struggling readers in each of the ten classes). This performance indicates an average success rate of 17.27% ($SD=7.47$) for struggling readers, significantly lower than the typical readers' average of 69.41% ($SD=21.05$) (typical decoders). These results placed struggling readers below the 30th percentile, which is under the norm according to the test battery standards. This threshold, as suggested by Torgesen (2000), effectively differentiates children requiring the most support, as phonological decoding is a fundamental skill in early reading development. This skill is crucial for the effective use of phonetic cues, enabling the development of word recognition fluency, which is essential for reading comprehension (Torgesen, 2000). After establishing these groups of readers, differences in other literacy measures were examined. Struggling readers also exhibited significantly lower performance across all literacy measures examined, at both the word and text levels, including MA and spelling, compared to their typical peers (for detailed results, see Table 1 in the 'Results' section).

Struggling readers, identified by the school's reading specialists, received 2–3 h of support per week from special education teachers, emphasizing the focus on educational needs in their identification process. The remaining participants ($n=213$) were classified as typical readers. The research received approval from the Ministry of Education in Israel as part of a community project.

Research tools

A two-part morphological awareness (MA) test and reading assessments were utilized, as described in the subsequent sections.

Morphological awareness test

To assess MA in second-grade students, a two-part test was administered, comprising distinct and separate sections focusing on inflections and derivations. While both components were part of the same overall MA assessment, they were presented as individual tasks to emphasize their unique aspects of morphological awareness. This test, previously employed and validated in various studies (Vaknin-Nusbaum et al., 2016a, b; Vaknin-Nusbaum, 2018), was revised in 2021 (see Vaknin-Nusbaum & Sarid, 2021) to include more than two optional answers for each item, to minimize the probability of choosing the correct answer by guessing. The students were required to choose one out of three answers for each item.

The test included commonly used words found in children's everyday language (e.g., table, window, ball) and textbooks. During the test, students were presented with two printed examples, and additional examples were provided as needed until children completely understood the tasks. Each question was displayed visually on a screen while being read aloud to the students. They were then instructed to circle the correct answer for each item, and no time limit was imposed. This approach aimed to minimize the impact of reading skills on MA. In this study, a condensed version of

the test was utilized, encompassing a possessive subtest (9 items) and a derivational analogy task (9 items).

To validate that students' performance on the MA test truly reflects morphological understanding rather than random guessing, a one-sample t-test was conducted comparing the mean scores of the Inflections and Derivations subtests to the guessing level of 33.3%. The analysis indicated significant exceedance of the guessing level (Inflections: $t=14.56$, $p<.001$; Derivations: $t=3.56$, $p=.00043$).

Inflections Children were presented with 9 items. To identify the correct inflection out of three given options, children were required to linearly decompose the presented word into its morphemes in order to locate the suitable suffix. For example, they were presented with a singular target noun and a possessive word (my, his, her, etc.) (e.g., *hatik shelahem hu* …' their backpack is…'). Next to the noun and the possessive word, there appeared three complex bound possessive forms separated by a diagonal line (***tikam****/ tiko / tiki* 'their backpack / his backpack / my backpack'). The correct choice appears here in bold type. Note that, unlike in English, the Hebrew possessive form is expressed as a bound suffix specific to each possessive inflection. The Cronbach's α reliability for the possessive inflections score at the beginning of the second grade was within the range of α=0.80–0.81 in previous studies (Vaknin-Nusbaum & Sarid, 2021; Vaknin-Nusbaum et al., 2016a, b) and 0.78 in this study.

Derivation The derivations part includes 9 items (maximal score) and requires performing an analogy task. All items were regular and fully tri-consonantal, with no missing elements (Ravid, 1995; Schwarzwald, 2001). After being shown examples, the students were required to choose the correct infinitive transformation out of the three given options, separated by a diagonal line. The distractors included a word with the same root as the root source, but not with the same pattern, and a word with the same pattern as the word source but with a root unrelated to both source and target (e.g., *lishmor – shmira* 'to guard – guarding' is like *likshor – **kshira*** / *kesher* / *shtifa* 'to tie – tying / a tie / washing'). The correct choice appears here in bold type. Also, note that in Hebrew, these word pairs are examples of derivations. To identify the correct derivation (e.g., *kshira*), the child was required to analyze the morphological root-and-pattern structure of the example, locate the new root (e.g., the root K.SH.R of the word *likshor*), and weave it into the morphemic pattern introduced in the example (e.g., the pattern of the word *shmira* – CCiCa). The Cronbach's α reliability for the derivations score at the beginning of the second grade was within the range of α=0.80-0.90 (Vaknin-Nusbaum & Sarid, 2021; Vaknin-Nusbaum et al., 2016b) and 0.84 in this study.

The MA score of each subtest was the sum of correct answers out of the total number of items in that subtest, calculated as a percentage score.

Reading and vocabulary tests (Age-Normed)

The Hebrew assessment battery of group reading measures—Elul (Shatil et al., 2007)—consists of tests for orthographic word recognition, phonological decoding, and reading comprehension, all presented, for first-grade levels, in pointed Hebrew orthography. Developed with age-appropriate versions from first to ninth grade, this battery was validated with 495 s-grade students (Shatil et al., 2007) and has been used in numerous studies on reading skills at elementary schools (e.g., Bar-Kochva, 2013; Horowitz-Kraus et al., 2014; Nevo et al., 2015; Vaknin-Nusbaum, 2018; Vaknin-Nusbaum et al., 2016a, b). To ensure a representative sample for the normative study, the developers selected schools from a national list, reflecting Israel's diverse geographical areas, educational streams (state or state-religious), and socioeconomic statuses.

Orthographic word recognition test Students were instructed to identify and circle words that named animals familiar to them from their spoken language within a limited time frame. The test consisted of 80 words; 25 of them represented animals (maximal score). The scores were calculated as the percentage of the total number of correct words. The test yielded a Cronbach's α of 0.94, which is consistent with the reliability reported in the battery manual.

Phonological decoding test The stimuli were homophonic pseudowords. Students were instructed to circle pseudowords that sounded like food (e.g., 'bread/bred' [/brɛd/]) within an allotted time. The test enabled children to associate novel letter sequences with familiar words by accessing their phonological lexicon. The test for second graders contained 78 pseudowords, 22 of which sounded like food items (maximal score). The scores were calculated as the percentage of the total number of correct words. The test yielded Cronbach's $\alpha = 0.89$ for second graders according to the manual and 0.87 in the current study.

Orthographic word recognition and phonological decoding tests were chosen because they examine essential skills involved in reading comprehension and reading acquisition and because they can distinguish between struggling and typical readers (Ziegler & Goswami, 2005). It's important to note that both tests contain morpheme patterns and that recognizing some of these patterns might assist the children in reading words and pseudowords.

Reading comprehension Students were asked to read two narrative texts, 'Efrat and her father' and 'The fairy and the goose,' and answer eight true/false questions about their content. Considering that most Hebrew words consist of at least two morphemes (a root and a pattern), almost every word in these texts was inherently complex. The first text included 75 out of 75 complex words out of 78, and the second had 67 out of 68.

Additionally, 16 to 18 words in each text included a function letter at the beginning. Furthermore, between 9 and 10 words in each text had further morphemic

complexity due to possessive inflection morphemes, which were simplified in the decomposed versions of the texts (refer to the text manipulation section for details). The composite reading comprehension scores for each text ranged from 0 to 8, calculated as a percentage score of accurate responses. To determine whether students' performance on the reading comprehension tests succeeded the guessing level, a one-sample t-test was conducted on the combined scores of the dense and decomposed comprehension tests. The analysis showed that the mean scores for both tests significantly exceeded the midpoint score of 50% (dense: $t=10.16$, $p<.001$; Decomposed: $t=11.05$, $p<.001$), indicating a level of comprehension well beyond mere guessing. The tests Cronbach's $\alpha=0.88$ according to the manual and yielded Cronbach's α of between 0.76 (first text) and 0.80 (second text) in the current study.

Text manipulation Two texts, picked from a reading battery test targeted at identifying struggling readers (Shatil et al., 2007). Each of the two texts was printed in two variants: one with dense inflections and another where dense words were separated into individual words. This configuration resulted in two versions of each text, one being linearly dense (multi-affixed) and the other decomposed. That is, all linearly composed dense words (non-obligatory) that appeared in texts were replaced by a simpler chain of words. The word *tiki* (consisting of the word *tik* and the suffix *–i*) 'my backpack' for example, was replaced with the two words *hatik sheli* that represent the same meaning in a less morphologically complex manner. This was achieved by replacing the suffix *–i* with the word *sheli* (my). Thus, deconstruction of the words in the text resulted in a longer text. In one text, 10 words were decomposed, while in the second, 9 words underwent this process. Consequently, an equivalent number of words were added to each text. The first text contained 78 words in its dense form and 88 in the decomposed version, while the second text had 68 words in the dense version and 77 in the decomposed version. The texts were presented in pointed transparent orthography due to the young age of the participants who were in the process of reading acquisition.

The order of text reading was systematically rotated among children to control for the possible effect of the content of the story. All participants read both versions of the two texts, with the decomposed and dense versions alternating. This approach ensured that each text, in both versions, was read an equal number of times across the participants. The assessment was conducted in groups of ten, where each participant silently read each text and subsequently responded to the accompanying questions.

Vocabulary Students were asked to look at four pictures and choose the one that represented the word that was read aloud to them by the research assistant. The test

had 26 words arranged by level of familiarity. The test yielded Cronbach's $\alpha = 0.82$ for second graders according to the manual and 0.84 in the current study.

Spelling recognition (Age-Normed)

This test is based on the Alef-Taf standardized assessment battery of reading and writing disabilities in Hebrew (Shany et al., 2006). The test was developed and validated using a sample of 429 s-grade students. Students were presented with 20 pairs of written words. Each pair consisted of one word spelled correctly and its counterpart, in which the misspelling involved replacing a single homophonic letter with another. Students were tasked with selecting the correctly spelled word from each pair. The test yielded Cronbach's $\alpha = 0.79$ for second graders according to the manual and 0.89 in the current study.

Procedure

Data were collected in October, approximately a month after the start of the academic year in schools. All tests were administered to participants in groups of 10 students by a research assistant. The home classroom teacher was present during the test administration to ensure the cooperation of the children. Each student received a notebook and was instructed to listen carefully to the given instructions, which were included on each test sheet and read aloud by the research assistant. Written examples were provided first, and each subtest commenced once the training items had been answered accurately. The tests were conducted over two sessions within the same week, in the following order: orthographic word recognition, phonological decoding, reading comprehension, MA, and spelling. The percentage of correct answers was calculated for each test individually. The total administration time was approximately 50 min (about 25 min per session).

Results

Descriptive and achievement differences between reader groups

The descriptive statistics for raw scores on word reading measures, MA, vocabulary, reading comprehension in both text forms (dense and decomposed), and spelling are presented in Table 1. Mean scores and standard deviations are displayed for the two groups of decoders: struggling readers and typical readers. A one-way MANOVA analysis was conducted to examine differences in literacy performance between the two groups. The independent variable was the *reading ability group* (struggling readers/typical readers), while the dependent variables included reading, MA, vocabulary, and spelling scores.

The results revealed a significant effect of the *reading ability group* on all assessed measures ($F(8, 280) = 59.05$, $p < .001$). The respective F-values and significance levels for each dependent measure can be found in Table 1. Significant differences were

Table 1 Means, SDs'and repeated measures MANOVA results of reading measures, MA and vocabulary, comparing poor and typical decoders, at the beginning of second grade

Phonological decoding level:	Poor ($n=79$)		Typical ($n=213$)		F values (df=1,289)	η^2
	M	SD	M	*SD*		
Word recognition	50.31	27.37	80.41	23.91	80.55***	0.47
Phonological decoding	17.27	7.47	69.41	21.05	451.14***	0.78
Inflections awareness	42.33	25.78	64.82	28.70	38.56***	0.35
Derivational awareness	27. 19	20.11	45.31	25.97	28.86***	0.31
Vocabulary	56.52	20.75	63.33	19.04	7.83**	0.15
Comprehension dense text	52.60	22.78	63.67	21.99	14.51***	0.21
Comprehension decomposed text	49.91	22.16	70.32	20.07	55.17***	0.40
Spelling	43.11	26.61	62.48	23.70	33.33***	0.33

**$p=.005$

***$p<.001$

observed between the two reader groups across all examined variables, favoring the typical readers who demonstrated better performance than their struggling readers peers.

Correlations between study variables

To explore the correlations among different facets of reading performance, vocabulary, MA, and spelling within two separate groups of readers— struggling readers and typical decoders—Pearson correlation analysis was performed for each reader group. Additionally, a Fisher r-to-z transformation was performed to compare the correlation coefficients between struggling readers and typical readers, with a specific focus on the relationships between MA (both inflectional and derivational) and reading comprehension (dense and decomposed texts). The correlation coefficients and Fisher transformation results are provided in Table 2.

Overall, Table 2 shows that regardless of reader types, MA seems to have an important role in literacy skills (spelling in particular). For instance, MA is positively and significantly correlated with word recognition, spelling, and comprehension in both text forms for both groups. Among typical decoders, all literacy measures are

Table 2 Pearson correlation coefficients comparing MA and literacy measures between TD and PD with Fisher r-to-z transformation

		Inflections awareness			Derivational awareness		
Comparison Groups	Variables	r_a	r_b	*z-value*	r_a	r_b	*z-value*
Typical Decoders$_a$/Poor Decoders$_b$	Word recognition	0.43**	0.38**	0.45	0.48**	0.52**	-0.4
	Phonological decoding	0.41**	0.21	1.66	0.33**	0.08	1.96*
	Vocabulary	0.18**	0.20	-0.16	0.18**	0.33**	-1.2
	Comprehension dense	0.20**	0.25*	-0.39	0.30**	0.34**	-0.33
	Comprehension decom.	0.21**	0.45**	-2.03*	0.32**	0.38**	-0.51
	Spelling	0.34**	0.45**	-0.98	0.51**	0.64**	-1.46

Note *$p<.05$; **$p<.01$. All z-values are two-tailed

significantly correlated with MA, including phonological decoding – which involves reading new unfamiliar words. Among struggling readers, significant correlations were found between MA (both inflectional and derivational) and word recognition, as well as between derivational awareness and vocabulary. There were also significant correlations between MA and both types of text comprehension (dense and decomposed), as well as spelling. The results of the Fisher transformation analysis indicate that the z-statistic for inflections and derivations in dense comprehension text was not significant, suggesting no significant difference between the group of readers. However, a notable z-statistic for inflectional awareness in decomposed text was found, suggesting a statistically significant advantage for struggling readers in this aspect.

Interaction between text type and reading ability group

To examine the interaction effects between *comprehension scores for each text type* (dense or decomposed) and *reader group* (struggling readers or typical readers), a two-way ANOVA with repeated measures was conducted. In this analysis, *comprehension scores for each text type* served as a 'within-subjects' factor, while the *reader group* (struggling readers vs. typical readers) was considered a 'between-subjects' factor, with vocabulary acting as a covariate. This analysis enables the examination of the interaction between *reader group* and *comprehension scores for each text type*, with the aim of determining whether these factors affected comprehension performance differently for the two groups.

A significant main effect of *reader group* was observed ($F(1, 287) = 48.60$, $p < .001$), indicating overall differences in comprehension performance between typical and non-typical readers, irrespective of text type. However, the main effect of *text type* on comprehension performance was found to be non-significant. Additionally, a significant interaction effect was found between *reader group* and *comprehension scores for each text type* ($F(1, 296) = 6.35$, $p = .012$, $\eta^2 = 0.02$). This interaction indicated that the influence of *text type* on comprehension performance varied significantly between struggling readers and typical readers. Further pairwise comparison results were adjusted by the Bonferroni correction to counteract the problem of multiple comparisons. The Bonferroni-adjusted post-hoc analysis revealed that within the group of typical readers, there was a statistically significant difference in comprehension scores between the dense and decomposed texts ($p < .001$, Bonferroni-adjusted), with higher scores observed for the decomposed texts. Conversely, among struggling readers, no significant differences were found between the two text types ($p > .05$, Bonferroni-adjusted), indicating that their comprehension was not differentially affected by text density.

Data presented in Fig. 1 demonstrate that readers with higher abilities not only achieve higher scores in both dense and decomposed texts but also exhibit a distinct advantage when engaging with decomposed texts.

Following these results, paired t-tests were conducted within each reader group to compare the reading comprehension scores for the two text types. Among struggling readers, there were no significant differences in performance scores between the two texts ($t(1, 76) = 0.78$, NS). In contrast, the group of typical decoders exhibited better

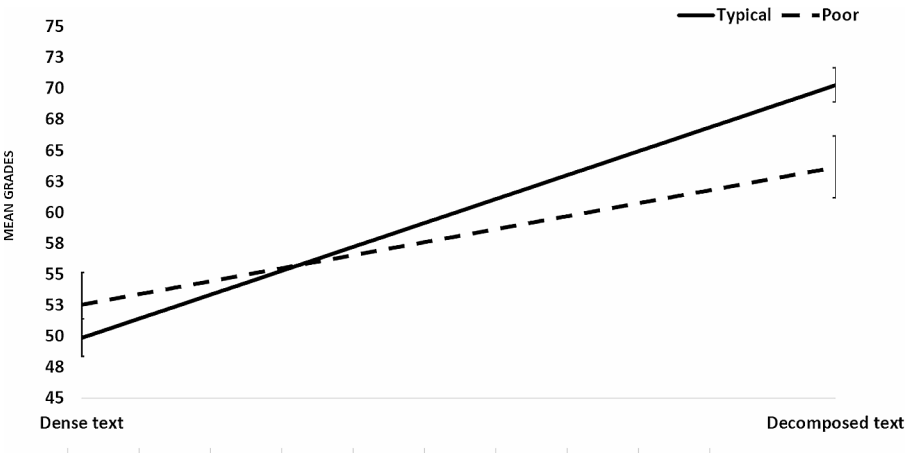

Fig. 1 Interaction between text type and reading ability group

performance in the decomposed simple text than in the dense text (t (1, 211) = -3.8, $p < .001$).

Discussion

The primary aim of the current study was to explore the relationship between morphological density in Hebrew texts and reading comprehension among Hebrew-speaking second graders, from a low SES background, at the onset of their academic year. Since these relationships can be influenced by reading proficiency, the effect of text density (type) was examined among struggling readers with poor decoding skills and their peers with typical skills. For a comprehensive understanding, differences in literacy achievements, including MA, between the two groups of readers were examined, as well as correlations between the study variables. The interactions between reader group and comprehension scores for each text type were examined to learn about the differences in the effect of text density on reading comprehension between typical and struggling readers.

Results showed differences between the two reader groups across all examined variables, favoring the typical readers who demonstrated better performance than their peers, the struggling readers. That is, the struggling readers showed poor decoding skills and also poor performance in other literacy aspects, including MA. Moreover, both types of MA were correlated with performance in both text types among both groups of readers, pointing to its important role in the process of reading. Fisher r-to-z transformation results revealed that the correlation between inflectional awareness and reading comprehension performance in the decomposed text was higher among underachievers. Finally, an interaction effect between reading ability group and comprehension scores for each text type was found, suggesting that text type has a different influence on comprehension performance for each of the two groups of readers. The differences in reading comprehension performance between the two

texts, dense and decomposed, were found only among the typical readers, favoring the decomposed version.

Current results corroborate the significant role that MA plays in the reading process, especially in Hebrew, a language renowned for its morphological density. Novice readers who showed poor decoding skills were also underachievers in other literacy measures, showing poor performance in MA, vocabulary knowledge, word recognition and spelling. Their lexical mental representations are lacking both in terms of quantity and quality. It is possible that it is challenging for them to establish new sub-lexical morphemic mental representations when they struggle with phonological decoding. As a result of these poor decoding skills, they also struggle to comprehend what they read and are less available for learning other knowledge that supports their mental representations and reading process. Thus, these difficulties are reflected in reading comprehension of both text types. Focusing on phonological decoding overshadows awareness of morphemes. Whether the words are dense or not, the readers seem to reach similar results, suggesting they might not rely on morphological strategies. According to dual-route models, dense words are expected to be decomposed into sub-units (morphemes) to access their representation and meaning (Baayen et al., 1997; Chialant & Caramazza, 1995). However, for this route to be used, awareness of morphemes needs to be developed to enable the formation of morphemic mental representations (Shimron, 2006; Vaknin & Shimron, 2011) that support the quality of lexical representation (Perfetti, 2007). Such representations develop over time as a result of accumulated experience and exposure to complex forms in speech and print (Frost, 2012; Share, 2018; Shimron, 2006; Vaknin & Shimron, 2011). This process, according to Seymour (2006), can be achieved after novice readers gain basic reading skills such as phonological decoding. In the context of the current study, participants might find it challenging to build morphemic representations alongside reading acquisition and use available linguistic information attached to a word to gain meaning when basic decoding skills are not acquired yet. Although some novice readers seem to be able to do it, as suggested by Frost (2012) and Share (2018), and supported by Vaknin-Nusbaum and Sarid (2021) findings collected from Hebrew-speaking second graders, some level of threshold of reading skills and MA should be reached before attention can shift to the morphemic level. Previous studies show that the second-grade period can be crucial in this regard and some novice readers rapidly improve their MA throughout the school year and exhibit a major jump in reading achievement (Vaknin-Nusbaum & Sarid, 2021). It should be noted that, in addition to their reading difficulties, children with poor decoding skills in this study were also found to have low vocabulary knowledge. Since vocabulary knowledge is related to the development of other language domains (Coyne et al., 2010, 2019), including MA (Goodwin & Ahn, 2010, 2013), low vocabulary knowledge serves as an obstacle in acquiring reading skills and directly and negatively affects reading comprehension (Biemiller & Boote, 2006; Manu et al., 2021; Suggate et al., 2018). The compounding effect of low vocabulary and poor MA is particularly significant in low SES populations, where these deficits can lead to a cascading effect on overall literacy development (Apel et al., 2013; Colé et al., 2018). The struggling readers who participated in this study can be referred to as having a double deficit: poor reading skills and a lack of language knowledge. While reading, these struggling readers

might find it challenging to discern whether their misunderstandings stem from poor reading skills or from insufficient background language knowledge.

Nonetheless, one should bear in mind that while struggling readers as a group do not show a preference for either dense or decomposed texts, Fisher r-to-z transformation results showed that struggling readers exhibit a heightened sensitivity to inflectional awareness in decomposed texts. This suggests that, within the struggling readers group, those with better inflectional awareness might perform better in decomposed texts. This could indicate that when the text is less dense, they might be able to use their awareness as a compensatory mechanism to counterbalance their substantial challenges in phonological decoding. However, this increased sensitivity to inflectional awareness does not translate into a marked improvement in their overall performance in decomposed texts when compared to dense texts. Within the struggling readers group, while inflectional awareness is a relevant factor for comprehension in decomposed texts, it appears insufficient to create a noticeable difference in overall performance between the two text types.

Typical readers, on the other hand, who performed better than their struggling-reader peers in all tests, seemed to be influenced by the type of text presented to them. Their reading comprehension was better when reading the decomposed text compared to the dense text. This difference in comprehension can be attributed to the inherent challenges associated with processing complex word structures. Understanding complex, dense words requires both linear and non-linear decomposition processes. The linear decomposition involves separating the bound morphemes from the words, while the non-linear decomposition requires extracting the root morphemes, which convey the core meaning of a word. In the decomposed version of the text, these linear complex forms, which are constructed from bound morphemes, were simplified. This typically involved converting one dense word into two simpler words. It's reasonable to assume that the root morpheme becomes more evident when words are stripped of their possessive morphemes. This allows readers to focus more effectively on the core meaning of words. As previously suggested, morphological transparency might facilitate the use of morphological cues in reading (Ravid, 2005; Ravid & Mashraki, 2007; Vaknin-Nusbaum & Saiegh-Haddad, 2020).

The decomposed version might also be more reader-friendly. This is because dense forms tend to appear more frequently in written texts than in everyday speech. Such complexity poses a challenge for novice readers, especially when they are confronted with these less common, morphologically complex forms. To understand these forms, awareness of their linguistic elements is needed. This awareness aids in the construction of more qualitative representations. Although typical readers show better reading achievement than their struggling peers, it's worth remembering that these typical readers are still developing. They are in the process of forming their sub-lexical and lexical representations as they continue to read. Thus, they can make better use of MA, particularly when linear possessive inflections are decomposed. This decomposition allows them to focus on the remaining complex forms. Given that almost every word in Hebrew consists of two morphemes, a pattern and a root, novice readers still have much to face with, even after the reduced overload from decomposing linear dense words.

One might have expected that the decomposed text would be beneficial to the group of struggling readers, rather than the other way around, as has been found among fifth-grade Arabic-speaking students (Asadi et al., 2024). In this study, it seems that struggling readers with poor decoding skills do not possess the tools to benefit from the less dense, decomposed text. The differences in findings might be attributed to the early reading acquisition phase of the participants in this study, who were at the beginning of the second grade. By the end of the first grade, children are expected to master grapheme-to-phoneme translation and to focus on developing fluency throughout the second grade (it's noteworthy that Hebrew-speaking children learn to read in a transparent orthography). MA may support the development of reading fluency (Vaknin-Nusbaum, 2021). Decomposed text might be helpful at this stage of development for novice readers. Those students who lag behind are still in the process of acquiring the milestones of reading, and therefore are not affected by text manipulation. Future research should explore the developmental aspects of the density effect among various groups of readers, aiming to pinpoint when readers transition to a morphological strategy and rely less on phonological decoding. This shift in reliance, from phonological to morphological strategies, appears to align with certain developmental milestones in the reading process. Previous studies suggest that as phonological decoding improves during the second grade, novice readers might rely more on morphological cues for reading comprehension (Vaknin-Nusbaum & Sarid, 2021). As these skills evolve and intertwine, the balance between phonological and morphological strategies can shift, paving the way for better performance in reading comprehension.

It might be reasonable to consider the development of MA among students with poor decoding skills, providing them with an additional strategy to recognize words and understand their meanings. This would be alongside strengthening their decoding abilities. Both these processes can reinforce lexical representations, equipping them with tools for better reading comprehension. As previously suggested, it's also worth considering the possibility that readers may differ in how they employ their morphemic awareness during reading. Some novice readers might use their awareness for comprehension during the reading acquisition phase, while others might benefit from their morphemic knowledge only after achieving a certain level of reading performance and bolstering their morphographic representation storage (Vaknin-Nusbaum & Sarid, 2021).

Another realm in which MA can be of great use is for improving spelling. Although the focus of the study was on reading comprehension, the strong positive relationship between MA and spelling surely indicates its importance to other literacy domains that should be investigated. The correlation showed the important role of both inflectional and derivational awareness in this regard, providing another reason for implementing the cultivation of morphemes alongside reading acquisition.

Despite the importance of the current findings, several aspects merit consideration. Firstly, it is crucial to note that the study's participants were from low SES backgrounds, a factor often associated with risks in language and literacy skill development (Nevo et al., 2023). Given this context, it becomes relevant to question how the study's outcomes might differ in various socioeconomic environments. One might ponder whether children from higher SES backgrounds, who likely have

access to richer linguistic environments, would exhibit a similar pattern. These children, potentially possessing higher levels of MA and a more extensive vocabulary, might process both dense and decomposed texts with equal proficiency. This would suggest that the influence of text density on comprehension may differ in populations with stronger linguistic backgrounds. Such considerations point towards the need for future research to explore these dynamics more thoroughly, providing insights into the interplay between socioeconomic factors, morphological awareness, and reading comprehension across varied reader groups. Second, when considering the generalization of these results to other languages, it's crucial to understand the morphological and orthographic characteristics of each language. Third, other types of texts with varying complexities might yield different results. Fourth, the study focused on second graders at the onset of their academic year. The findings might differ for older or more experienced readers, or for those just beginning to learn to read. Finally, the aspect of word frequency, particularly its prevalent occurrence within the linguistic experiences of the intended age group, was not controlled. The methodology ensured uniform exposure to the words across all textual materials for each participant, yet it did not include an adjustment for the overall frequency of these words in a broader linguistic corpus. This opens a dialogue for future investigations to investigate how the frequency of word exposure in everyday language might intersect with morphological complexity, thereby influencing reading comprehension.

In conclusion, the findings of this study underscore the widely acknowledged concept that 'the rich get richer' (Stanovich, 2009). Students with a strong foundation in language and reading skills noticeably benefited more from the decomposed, less dense texts. This differential interaction with text structures highlights the critical role of MA in reading processes. Educators might consider adjusting text density to align with a student's reading proficiency, especially in languages like Hebrew that inherently have morphological complexities. As students' reading skills develop, introducing high-density words in texts and teaching their structure might further improve their quality of lexical representations and subsequently enhance reading comprehension.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11145-024-10526-7.

Declarations

Competing interests The author has no conflicts of interest to declare.

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