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ORIGINAL ARTICLE

Morphological processing in the parafovea during sentence reading for deaf and hearing readers

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Abstract
Evidence of parafoveal preprocessing of morphology is mixed for typical hearing readers of English: they demonstrate a preview benefit from morphology for suffixed words but not for compound or prefixed words. Deaf readers may process morphological structure more efficiently in the parafovea due to their ability to attend to information further into the periphery and their particularly tight connections between orthography and semantics, which support morphological processing during initial word recognition. Morphological awareness has been shown to influence reading skill for both deaf and hearing readers, but little is known about how it affects their online processing during sentence reading. Using a gaze-contingent display change paradigm, we tested whether deaf and hearing readers with varying morphological awareness skills showed differences in parafoveal processing of morphology during sentence reading. We found that deaf readers with high morphological awareness showed a graded preview effect, with shorter gaze durations on target words ("sadness") following a pseudomorphological preview ("sadment") compared to a non-morphological preview ("sadnard"). Hearing readers were unaffected by the morphological preview, regardless of skill level. These results suggest that deaf readers are attuned to morphological structure in the parafovea during sentence reading, but only if they have a higher level of morphological awareness.

Keywords: Deafness and hearing impairment; morphosyntactic processing; reading

Introduction

Because of their reduced access to the sounds of spoken language, people who are prelingually and profoundly deaf rely more on orthographic information to access semantics during reading (e.g., Sehyr & Emmorey, 2022; Fariña et al., 2017).

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Given that in English spelling-to-meaning mappings are more consistent than spelling-to-sound mappings (Berg & Aronoff, 2017), deaf readers may also rely more on morphological structure to support lexical access. Deaf readers show equivalently precise orthographic representations as hearing readers despite less precise phonological representations (e.g., Meade et al., 2020), and rapid activation of orthographic codes may result in more efficient access to the semantic information of the word (see Bélanger & Rayner, 2015). In fact, for deaf readers, morphological awareness, or the ability to identify and manipulate component parts of complex words (Levesque et al., 2017), is significantly related to reading comprehension ability and vocabulary size (Saunders et al., 2026). Further, morphological awareness is related to English placement levels assigned upon entry to university for deaf students, while phonological awareness is not (Clark et al., 2011).

Deaf individuals also vary in their eye movements during sentence reading, with several studies demonstrating highly efficient reading patterns for signing deaf readers (Bélanger et al., 2012; Traxler et al., 2021). There are several hypotheses for the sources of this reading efficiency. Deaf individuals' allocation of visual attention tends to be distributed more widely across the visual field than for hearing individuals (Bavelier et al., 2006). This attentional distribution affects sentence reading, and studies with skilled deaf readers have demonstrated that they take in information from a wider area of the parafovea than skill-matched hearing readers, reaching up to 18 characters to the right of fixation compared to 14–15 for hearing readers (Bélanger et al., 2012). Being able to begin initial word recognition farther into the periphery may allow deaf readers to more efficiently process words once they land on them (see Traxler et al., 2021). Initial word recognition for deaf readers takes advantage of a more direct connection between orthography and meaning, bypassing less specified or precise phonological codes during word processing (Bélanger et al., 2012, 2013), and morphological processing is likely an important facet of this initial processing stage. However, online morphological processing has been understudied with deaf readers.

Morphological processing at the single-word level for hearing readers has been investigated using priming methods. These studies show that readers are faster to recognize a simple word if it is preceded by a complex (or pseudocomplex) prime containing that root, even if the prime is presented only for a short time (Rastle et al., 2004; Rastle & Davis, 2008). Priming studies indicate that readers break down morphological structure in the earliest stages of word recognition. During natural reading, this stage occurs while the word is still in the reader's parafovea, between 1° and 5° of visual angle from the central fixation. A parallel to priming in single-word recognition studies is the *gaze-contingent boundary paradigm* used in eye-tracking studies (Rayner, 1975). In this paradigm, preview information in the parafovea is changed to a target as a participant's eyes cross an invisible boundary preceding a target word. Participants typically do not perceive the display change because it occurs as their eyes move (saccadic suppression; Matin, 1974). Crucially, the information in the preview affects readers' eventual fixation on a target word, i.e., related information facilitates processing and decreases fixation time, while unrelated information inhibits/slows processing and increases fixation time. This pattern reflects the ability of readers to begin processing the word in the parafovea ahead of their first fixation on the word (Schotter et al., 2012). Thus, the paradigm is considered to be sensitive to the early stages of word recognition.

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Numerous studies have demonstrated an *orthographic preview benefit*: previews with related orthographic information to the target, such as transposed letters as opposed to substituted letters (e.g., macihne-machine vs. macabne-machine), resulted in larger preview benefits (shorter fixation durations on the target word) (Balota et al., 1985; Briihl & Inhoff, 1995; Drieghe et al., 2005; Johnson et al., 2007; Johnson & Dunne, 2012). Shorter fixation times are hypothesized to occur because the preview allows readers to initiate lexical processing, which facilitates lexical access for the target word when they fixate on it (Schotter et al., 2012). Deaf readers also show orthographic preview benefits, and this is true for both skilled and less skilled deaf readers (Bélanger et al., 2013).

Evidence for a *morphological preview benefit,* indicating that readers begin the initial stages of processing morphological structure in the parafovea, is mixed. Morphological preview benefits have been observed in German (Mousikou & Schroeder, 2019), Chinese (Yen et al., 2008), and Hebrew (Deutsch et al., 2000), but not English (Kambe, 2004; Lima, 1987) or Finnish (Bertram & Hyönä, 2007). In German, readers are able to extract the identity of embedded stems from pseudoword previews. Fixation durations on a real-word target (*bettlein*, "little bed") are shorter when preceded by a pseudomorphological pseudoword preview; that is, a preview created by combining a stem and a suffix that both exist in German but do not result in an interpretable meaning (*bettlich,* "bedly"). German readers also have shorter fixations after a nonmorphological pseudoword preview (*bettpern,* where "*pern*" is orthographically plausible but is not an existing German suffix) compared to an unrelated preview (Mousikou & Schroeder, 2019). Mousikou and Schroeder (2019) concluded that readers were able to begin processing the embedded stems in the parafovea, regardless of whether they were accompanied by an affix.

In English, the parafoveal preview benefit is not different for prefix-only compared to stem-only letter information (for a target word *review*: prefix preview *rexwsz* and stem preview *cmview*) (Kambe, 2004); that is, readers show preview effects from both types of partial preview, with no difference depending on whether the preview was the prefix or the stem. Kambe (2004) concluded that there was no evidence of morphologically motivated preprocessing in English sentence reading but rather that any related letter information in the parafoveal preview facilitated processing of a target. This result was consistent with Lima (1987), who also found no evidence of parafoveal preprocessing of prefix information.

Nonetheless, a more recent study found evidence of a morphological preview benefit in English, but only for suffixed words in which the root appears in the beginning part of the word (Dann et al., 2021). Previewing words with pseudomorphological suffixes such as *stressary* yielded a larger preview benefit effect on a target word (*stressful*) compared to preview words with nonmorphological endings (*stressard*). In contrast, readers showed no preview benefit from prefixed or pseudoprefixed words in which the root appears at the end of the word, replicating Kambe (2004). These results suggest that readers of English are able to decompose morphologically complex previews in the parafovea, but only when the more salient stem (as opposed to the prefix) falls in the highest acuity area of the parafoveal region directly next to the fixation (Dann et al., 2021). The authors additionally suggest that the legitimacy of the suffix (i.e., its status as a real English suffix, as opposed to a pseudosuffix) contributed a "boost" to the preview effect of the stem.

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Readers were more easily able to decompose (and therefore preprocess) the stem when it was attached to a familiar English suffix. These results are consistent with accounts of morphological decomposition in which stems and affixes are segmented according to orthographic characteristics, regardless of their true semantic relationship (Lavric et al., 2007; Rastle & Davis, 2008).

The combination of deaf readers' ability to attend to information further into the periphery and their sensitivity to orthography in early word processing may contribute to a greater ability to preprocess morphological structure compared to their hearing peers. Morphological processing in a sentence context has yet to be investigated for deaf readers and may be an important pathway from orthography to semantics in the absence of reliable or accessible phonological decoding. The extent to which deaf readers decompose morphological structure in the earliest stages of word recognition during sentence reading (i.e., while words are in the parafovea) will provide insight into the relationship between their robust orthographic-to-semantic mappings and their parafoveal processing abilities. In addition, morphological awareness ability has a stronger relationship with reading comprehension for deaf compared to hearing readers (Saunders et al., 2026), and thus morphological awareness might modulate the size of the preview benefit from morphologically complex words for deaf but not hearing readers.

Using a gaze-contingent boundary paradigm (Rayner, 1975), we tested whether deaf and hearing readers with varying morphological skill (objectively assessed by morphological awareness tests) extract morphological information from the parafovea during sentence reading, as evidenced by a morphological preview benefit. Based on research that suggests that morphological preview benefits in English are restricted to suffixed words (Dann et al., 2021), target words all consisted of a stem and a suffix, while preview words either had a pseudomorphological suffix ("sadment"), a nonmorphological suffix ("sadnard"), or were unrelated pseudowords ("florous") (see *Stimuli* for additional details). Given that previous research shows that longer words (e.g., multimorphemic words) are more likely to receive multiple fixations (Schotter & Dillon, 2025; Vergilino & Beauvillain, 2000), we selected gaze duration, the sum of all fixation durations a reader makes on a target word before moving past it, as our primary measure of initial word recognition.

We hypothesized that both hearing and deaf readers would have shorter gaze durations on target words following parafoveal previews that share a root with the target (i.e., both morphological ("sadment") and nonmorphological ("sadnard") previews) compared to unrelated previews ("florous"). Such a result would reflect the general orthographic preview benefit from the common letters (here, "sad-") between the parafoveal preview and the target word. Both deaf and hearing readers are expected to show a graded preview benefit, with the most benefit from pseudomorphological previews, then nonmorphological, then unrelated pseudoword previews (following Dann et al., 2021). However, if deaf readers are indeed more attuned to morphology, they should show a stronger preview benefit from the aspects of the preview specific to morphological structure. In other words, deaf readers should be better able to extract the informative root ("sad-") from a pseudoword with an apparent morphological structure (a valid English suffix, "-ment") than from a pseudoword with no apparent suffix (a meaningless letter string, "-nard"). Greater morphological sensitivity would result in a larger

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difference in fixation time between the pseudomorphological ("sadment") and nonmorphological ("sadnard") conditions compared to the hearing readers. The comparison between the nonmorphological and pseudomorphological preview conditions should therefore index the difference in parafoveal morphological processing between the two groups. These processing differences may also be impacted by morphological awareness, as deaf and hearing readers differ in both their morphological awareness skills and the relationship between this skill and overall reading comprehension.

Methods

Participants

Two groups of adult participants were recruited: 1) twenty-four hearing, monolingual English speakers (15 women, mean age = 30.4 years, SD = 13.3 years), and 2) twenty-four prelingually and severely/profoundly deaf signers (13 women, mean age = 36 years, SD = 8.7 years). All deaf participants learned American Sign Language (ASL) before age 7 (M = 2.07 years, SD = 2.94 years) and use ASL as a primary means of communication. All participants had normal or corrected-to-normal vision and reported no reading or learning disabilities. Background information (education, knowledge of other languages) was collected for both groups. Hearing participants reported an average of four years post-high school education (SD = 1.26). Deaf participants reported an average of 5.48 years post-high school education (SD = 3.35 years).

Assessments

In addition to the eye-tracking experiment, participants also completed a battery of reading assessments, summarized below. The groups were matched on reading skill ($p = 0.19$) and spelling skill ($p = 0.99$). The hearing readers had larger vocabularies ($p = 0.01$) and performed better on the morphological awareness tests ($p < 0.001$). Morphological awareness was correlated with reading comprehension for both groups (Deaf: $r(24) = .66$, $p < 0.01$; Hearing: $r(24) = 0.60$, $p < 0.01$); the relationship is numerically though not significantly stronger for the deaf readers than the hearing readers ($z = 0.32$, $p = 0.75$). See Table 1 for a summary of participant scores on reading assessments.

Woodcock Johnson IV passage comprehension subtest

Participants read short passages (1–2 sentences) containing one blank and filled in the blank with the correct missing word (LaForte et al., 2014). Raw scores were calculated by subtracting errors from the ceiling item (maximum score 47). This test measures readers' general reading comprehension level.

Test of receptive spelling

Participants were given a list of 87 printed words, some of which were spelled incorrectly, and asked to circle only the incorrectly spelled items (Andrews & Hersch, 2010). Raw score was calculated by subtracting errors (i.e., missed

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Table 1. Mean scores on assessments for each participant group (standard deviations reported in parentheses)

Assessment	Deaf readers	Hearing readers	*P*-value (*T*-test)
WJ IV (passage comprehension)	36.5 (4.8)	38.04 (2.97)	0.19
Receptive spelling test	72.88 (8.34)	72.83 (7.78)	0.99
PPVT-IV	198.54 (15.86)	208.92 (9.64)	0.01
MTMS part 1 (derivation)	6.88 (2.58)	8.92 (2.12)	<0.001
MTMS part 2 (decomposition)	9.42 (3.12)	12.7 (1.42)	<0.001
Nonword choice task	11.71 (2.49)	14.12 (2.31)	<0.001
MTMS (parts 1 and 2) and nonword choice task (summed score)	28.125 (6.80)	35.8 (4.52)	<0.001

"incorrect" words or falsely circled "correct" words) from the total number of words (87). Because this test does not involve dictation or auditorily presented test items, it is an appropriate and comparable measure of spelling skill for both deaf and hearing readers.

Peabody picture vocabulary test IV (PPVT-IV)

In the adapted version of the PPVT-IV, participants read an English word in the center of a page and are asked to identify which of four pictures on the same page is the most accurate representation of the English word (Dunn & Dunn, 2007; Sarchet et al., 2014). Raw scores were calculated by subtracting errors from the ceiling item (maximum score 228). This test represents participants' vocabulary size.

Modified test of morphological structure (MTMS)

In part one of this assessment (derivation), participants were provided with a simple root word and a sentence containing a blank, then asked to derive a complex word using the root that fits a sentence frame. In the second part (decomposition), participants were provided with a complex word and another sentence frame that contained a missing word, then asked to remove an affix or affixes from the complex word to produce the simple word that successfully completes the sentence (Bernstein et al., 2020). See Table 2 for example items. Part 1 (derivation) measures participants' ability to generate complex words by applying the correct affixes to a root word (15 total items). Part 2 measures participants' ability to identify which parts of complex words are the roots and affixes and then extract the appropriate root based on the sentence context (15 total items).

Nonword choice task

Participants were provided with a sentence containing one orthographically plausible nonword that contains possible English affixes (e.g., acquitation) and asked to choose from three options to identify the most plausible meaning for the

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Table 2. Example items from MTMS and nonword choice tasks, comprising the measure of morphological awareness

Task	Example item	Correct answer
Modified test of morphological structure (part 1: derivation)	Assist. The teacher will give you _____.	Assistance
Modified test of morphological structure (part 2: decomposition)	Discussion. The friends have a lot to _____.	Discuss
Nonword choice task	On the property was a PERIMETOUS wall. Answer options: - Encircling - Deteriorating - Rough stone	Encircling

nonword (McCutchen & Logan, 2011). See Table 2 for example items. This task assesses participants' ability to infer the meaning of novel words by using familiar affixes and roots (18 items).

Participants' summed scores on the MTMS and the Nonword Choice Task comprised our measure of morphological awareness (MA). Raw scores were calculated by subtracting errors from the total number of items (48).

Stimuli

The stimulus set contained 256 sentences with a morphologically complex target word located in the middle of the sentence, with four preview conditions (see Figure 1): identity, pseudomorphological pseudoword, nonmorphological pseudoword, and unrelated pseudoword. Participants read all 256 sentences, evenly distributed across four experimental conditions (64 per condition). The sentences were counterbalanced using four lists, ensuring that each participant read all 256 sentences and an equal number of participants encountered each sentence in each of the four conditions. Morphologically complex pseudowords were formed by combining the target root with an existing English suffix that does not form an existing English word. Nonmorphological pseudowords were formed by combining the target root with an orthographically plausible but meaningless string of letters that does not resemble English suffixes such as "-erp," "-rol," etc. Unrelated previews were formed by combining an unrelated root and an unrelated suffix to form a pseudoword with the same number of letters as the target. The three pseudoword conditions did not differ in bigram frequency (all $ps > 0.10$), as calculated by the CLEARPOND database (Marian et al., 2012). The average number of overlapping letters between the morphological pseudoword and the target word and between the nonmorphological pseudoword and the target word were 4.9 and 4.8, respectively ($t = 1.96$, $p = 0.1$), ensuring that apparent morphological structure was the only difference between the two related pseudoword conditions. Eighty-seven items were taken from Dann et al. (2021), and the remaining 169 items were constructed with the same parameters; see Table 3 for descriptive statistics of sentences.

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Table 3. Summary of the characteristics of the experimental sentences. Reading level was estimated using the Flesch-Kincaid readability formula (Flesch, 1948; Kincaid et al., 1975), and measures of syntactic complexity were calculated using the Haiyang Ai Web-based L2 Syntactic Complexity Analyzer (Lu & Ai, 2015)

Measure	Average (standard deviation)
Word frequency (log HAL)	11.94 (3.43)
Words per sentence	10.38 (1.45)
Word length	5.2 (2.56)
Number of clauses per sentence	1.27 (0.12)
Complex T-unit ratio	0.29 (0.08)
Estimated reading level (grade)	8.21 (3.5)

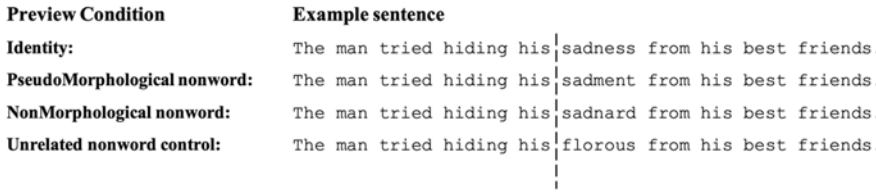


Figure 1. Example sentences with each type of preview condition. The vertical line indicates the location of the invisible boundary.

Procedure

Participants sat comfortably in front of a computer screen and silently read single-line sentences while their eye movements were tracked with an SR Research Eyelink 1000+ eye tracker in desktop configuration or an Eyelink Portable Duo. Stimuli were presented in 14pt black Courier New font on a light gray background on a 24-inch LCD monitor with a 1000 Hz refresh rate. The screen was placed 85 cm from the participants' eyes, providing ∼3.5 letters/degree of visual angle. Participants first performed a 3-point calibration and then read silently. When participants' eyes crossed the programmed invisible boundary, the preview word either changed from one of the different previews (in the display change conditions) or remained that same (in the identical condition). Participants pressed a gamepad button when they finished reading a sentence to move on to the next trial. To ensure they were reading for comprehension, participants answered Yes/No questions with buttons on the gamepad after 20% of the trials.

Analyses

The data were analyzed using a linear mixed effects (LME) model with random intercepts for item and subject, as models with more complex random effects structures did not converge. The fixed effects contained predictors for group (entered with a treatment contrast, with the hearing group as the baseline and the

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deaf group as the comparison), preview condition (entered with successive differences contrasts), and morphological awareness score (centered around group means). The preview condition was contrast coded using successive differences as follows:

1. Identity preview benefit: Pseudomorphological (sadment)—Identity (sadness)
2. Morphological preview benefit: Nonmorphological (sadnard)—Pseudomorphological (sadment)
3. Orthographic preview benefit: Unrelated (florous)—Nonmorphological (sadnard)

The morphological preview benefit, the second contrast testing the difference between fixation durations after the pseudomorphological compared to nonmorphological previews, was our primary contrast of interest because it represents the preview effect of morphological structure distinct from the orthographic overlap present in both related previews.

The model was fit with the lmer function from the lme4 package (Bates et al., 2015) in the R statistical computing environment. *P*-values were estimated using the Satterthwaite approximation method via the lmerTest package (Kuznetsova et al., 2017), and we used a standard alpha criterion of .05 to determine statistical significance. In addition to the primary analysis of the target word, we also report a comparison of comprehension accuracy and global reading measures (reading rate, mean fixation duration, and percent regressions) between the two groups.

Results

Comprehension accuracy

The groups did not differ significantly on comprehension accuracy (Deaf: Mean = 84% accurate, SD = 36%; Hearing: Mean = 88% accurate, SD = 32%; $t = -1.74$, $p = 0.07$).

Global sentence measures

When collapsed across preview condition, deaf readers had numerically faster overall reading rates (Deaf: M = 215 wpm, SD = 96.6; Hearing: M = 199 wpm, SD = 74.3), fewer percent regressions (Deaf: M = 10.1%, SD = 6.9; Hearing: M = 12.4%, SD = 6.0), and longer mean fixation durations (Deaf: M = 221.73 ms, SD = 37.1; Hearing: M = 212.33 ms, SD = 33.1). However, none of these differences were statistically significant in *t*-tests (all *p*s > 0.2) or LME models (main effects of group, all *p*s > 0.2).

Gaze durations on the target word

There was no significant effect of group, indicating similar gaze durations for deaf and hearing readers with average morphological awareness scores when collapsing across the preview condition. For hearing readers (the baseline group in the

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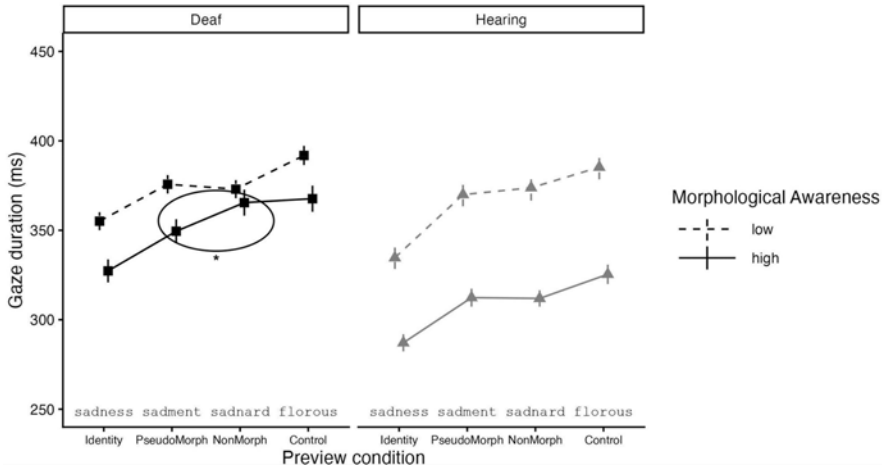


Figure 2. Interaction between group, morphological awareness, and preview condition. The circle highlights the three-way interaction between group, morphological awareness (visualized by median split), and preview condition (pseudomorphological ("sadment") vs. nonmorphological ("sadnard") previews).

analysis), there was a significant identity preview benefit (i.e., shorter gaze durations on the target in the identity preview condition than in the pseudomorphological preview condition, $p < 0.001$) and a significant orthographic preview benefit (i.e., shorter gaze durations on the target in the nonmorphological condition compared to the unrelated condition, $p < 0.05$). However, hearing readers did not show a significant morphological preview benefit (i.e., their gaze durations were similar on targets in the pseudomorphological and nonmorphological preview conditions, $p = 0.553$). For hearing readers, there were no significant overall effects of morphological awareness or two-way interactions between morphological awareness and any of the preview comparisons (all $ps > 0.123$).

There were no significant two-way interactions between group and any of the previous comparisons, suggesting that on average the groups were similarly sensitive to the manipulations. However, there was a significant three-way interaction between group, morphological awareness, and the morphological preview benefit. The interaction indicates shorter gaze durations on the target following the pseudomorphological preview compared to the nonmorphological preview for the deaf group, particularly for those with high morphological awareness, and no difference between preview conditions for the hearing group ($p = 0.049$, see Figure 2 and Table 4 for statistical results with effect sizes represented in the estimates column). The inclusion of the three-way interaction in the model resulted in a marginally better model fit than a model with only two-way interactions: $\Delta\chi^2$ $(3, N = 48) = 7.46$, $p = 0.059$.

To more clearly illustrate the three-way interaction indexing the different patterns of the morphological preview effect, we calculated the difference in average gaze duration after nonmorphological and pseudomorphological previews for each participant. A positive number reflects a preview benefit from the pseudomorphological

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Table 4. LME results, gaze duration

	Gaze duration			
Predictors	Estimates	Std. error	Statistic	*p*
(Intercept)	**335.87**	**17.76**	**18.91**	**<0.001**
Group	25.78	24.93	1.03	0.301
PseudoMorph—Identity	**29.93**	**4.99**	**6.00**	**<0.001**
NonMorph—PseudoMorph	2.95	4.98	0.59	0.553
Control—NonMorph	**12.06**	**4.98**	**2.42**	**0.015**
MA (group-centered)	−20.00	17.63	−1.13	0.257
Group * PM—ID	−7.92	7.06	−1.12	0.262
Group * NM—PM	1.70	7.06	0.24	0.809
Group * Ctrl—NM	−0.38	7.06	−0.05	0.957
Group * MA	1.60	24.91	0.06	0.949
PM—ID * MA	2.25	4.99	0.45	0.653
NM—PM * MA	−7.67	4.98	−1.54	0.124
Ctrl—NM * MA	2.69	4.98	0.54	0.589
Group * PM-ID * MA	0.26	7.06	0.04	0.971
Group * NM-PM * MA	**13.91**	**7.06**	**1.97**	**0.049**
Group * Ctrl-NM * MA	−0.93	7.07	−0.13	0.896
Random effects				
σ2	18560.49			
τ00 trial	1211.40			
τ00 subject_ID	7380.56			
ICC	0.32			
N subject_ID	48			
N trial	256			
Observations	11930			
Marginal R2/conditional R2	0.028/0.336			

condition, distinct from the orthographic preview benefit of the shared letters present in both pseudomorphological ("sadment") and nonmorphological ("sadnard") conditions. Figure 3 illustrates the group interaction between the preview condition and morphological awareness using these difference scores.

Additional eye-tracking measures on the target word

When collapsed across preview conditions, there was no main effect of group for first fixation duration, total viewing time, or refixation probability (all $ps > 0.44$),

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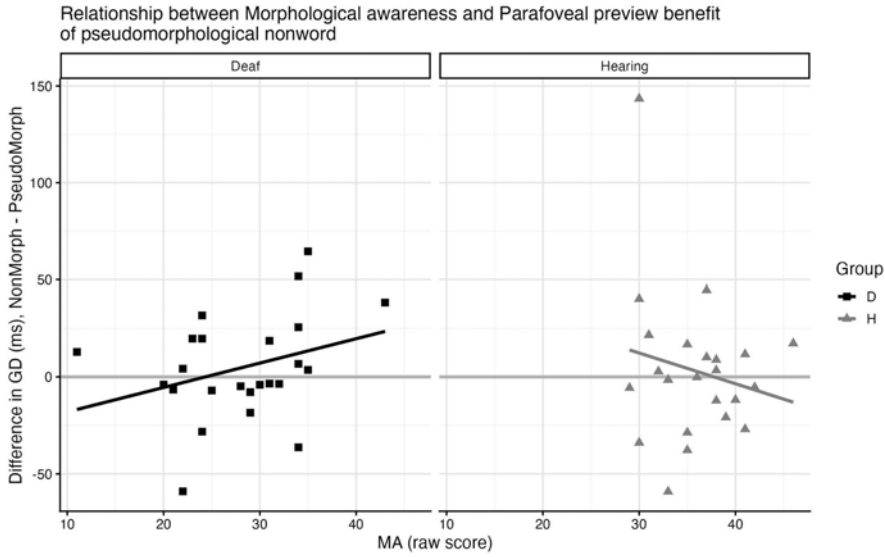


Figure 3. Relationship between morphological awareness and parafoveal preview benefit measured as the difference in gaze duration (GD) after nonmorphological versus pseudomorphological previews. A positive difference score indicates a preview benefit from the pseudomorphological preview.

but deaf readers regressed marginally less than hearing readers (deaf $M = 0.08\%$, hearing $M = 0.13\%$; $t = -1.78$, $p = 0.075$) (see Table 5).

In LME/GLME models with both group and preview condition as predictors, there was a marginally significant interaction between group and the orthographic preview benefit (unrelated—nonmorphological) for regression probability, such that hearing readers were slightly more likely to regress after the unrelated preview than the nonmorphological preview compared to the deaf readers ($p = 0.052$). There was also a marginally significant interaction between group and identity preview (pseudomorphological—identity) such that the hearing readers spent slightly less total time on the target after an identity preview compared to a pseudomorphological preview than the deaf readers ($p = 0.054$).

There were no significant group interactions with the morphological preview contrast of interest (nonmorphological—pseudomorphological) for first fixation duration, total viewing time, refixation probability, or regression probability (all $ps > 0.11$).

Discussion

The present study investigated parafoveal preprocessing of morphological structure for deaf and hearing readers using a gaze-contingent display change paradigm. As expected, we found a significant preview benefit effect of shared orthography with the target word (sadnard-sadness) compared to an unrelated preview (florous-sadness), indicating that both groups of readers initiated word recognition from a parafoveal preview and used the presence of shared letters to facilitate access to a

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Table 5. Summary of additional eye-tracking measures on the target word, summarized by group and preview condition

Measure	Preview condition	Deaf readers mean (SD)	Hearing readers mean (SD)
First fixation duration (ms)	Identity	270.14 (98.88)	254.70 (92.48)
	Pseudomorphological	279.17 (100.40)	271.04 (103.74)
	Nonmorphological	277.75 (99.67)	274.13 (101.62)
	Unrelated pseudoword	289.57 (112.03)	287.47 (116.57)
Refixation probability	Identity	0.97 (0.16)	0.97 (0.17)
	Pseudomorphological	0.98 (0.15)	0.98 (0.15)
	Nonmorphological	0.97 (0.17)	0.98 (0.14)
	Unrelated pseudoword	0.98 (0.15)	0.98 (0.13)
Total viewing time (ms)	Identity	406.54 (254.36)	367.35 (213.84)
	Pseudomorphological	425.63 (253.46)	408.51 (227.03)
	Nonmorphological	436.84 (260.19)	405.87 (225.52)
	Unrelated pseudoword	468.45 (294.66)	442.07 (244.08)
Regression probability	Identity	0.06 (0.24)	0.09 (0.29)
	Pseudomorphological	0.07 (0.25)	0.11 (0.32)
	Nonmorphological	0.08 (0.27)	0.12 (0.33)
	Unrelated pseudoword	0.13 (0.34)	0.21 (0.40)

complex target word once they fixated on it. We observed differences between the groups with respect to the pattern of morphological preview benefit and its relationship with morphological awareness. The deaf readers with higher morphological awareness exhibited a preview benefit from morphological structure in the parafovea (i.e., pseudomorphological previews resulted in shorter fixation durations than nonmorphological previews). For this group, the size of the preview benefit also increased with morphological awareness. This pattern suggests that deaf readers with higher morphological awareness were segmenting morphological structure in the earliest stages of word recognition. They were more easily able to extract the root when the suffix was a true suffix, even though this segmentation did not result in a valid English word (sadment), compared to when the suffix was not a valid English suffix (sadnard). This segmentation facilitated access to a morphologically complex target word, as evidenced by shorter gaze durations. The timing of this effect, given that the pseudomorphological manipulation was only visible while in the parafovea, indicates that morphological segmentation likely occurs in the pre-lexical stage of the processing stream, before readers become consciously aware of the meanings of each morpheme.

In contrast, the relationship between the morphological preview effect and morphological awareness for the hearing readers was smaller and trended in the opposite direction, indicating that the presence of morphological structure in the

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parafovea yielded no additional facilitation as morphological awareness increased. The relationship for the deaf readers with low morphological awareness was similar to that of the hearing readers. For both of these groups, a preview with shared letters, whether or not it had a valid morphological structure (sadment/sadnard), provided more facilitation than a preview with no shared letters (florous), indicating an orthographic preview benefit. In contrast, for deaf readers with high morphological awareness, a preview with shared letters but invalid morphological structure ("sadnard") provided no more facilitation than an unrelated preview. For this group, an invalid morphological ending (despite a shared root) may hinder the orthographic preview benefit demonstrated by the other groups in the current study. This pattern would suggest that without a familiar suffix indicating a morpheme boundary after the root, this group of readers was less able to segment the informative shared root in the nonmorphological preview ("sad" out of "sadnard") and initiate word recognition in the parafovea. Readers who have developed a strong awareness of morphological structure may prioritize this type of information when processing upcoming words that are likely to be morphologically complex, i.e., longer words. Longer words without an apparent morpheme boundary, like "sadnard," would thus be processed more similarly to a single-morpheme word, which may not allow these readers to identify the familiar root word in the short time the preview is available.

The results of the current study indicate that deaf readers with relatively good morphological knowledge were able to carry out initial morpho-orthographic segmentation in the parafovea when preview words had apparent morphological structure. Segmenting a preview word according to morphological structure facilitated their recognition of complex multimorphemic targets, allowing these deaf readers to more efficiently direct their attention (i.e., their fixations) to the long, infrequent target words.

Because this pattern was primarily observed for skilled deaf readers who had high scores in both morphological awareness and general reading comprehension, the unique reading profile of an individual deaf reader likely plays an important role in how they allocate their attentional resources. This could be an effect of morphological awareness or reading ability more generally. Deaf readers as a population tend to be more heterogeneous than hearing readers, and this trend is reflected in the wider variance in reading assessment scores in our deaf group. The relationship between morphological awareness and reading comprehension, while statistically significant for both groups, was slightly stronger for the deaf than the hearing participants in our sample. Therefore, when interpreting differences in online morphological processing for deaf readers, it is necessary to consider individual differences in reading proficiency, including and especially morphological awareness.

It is important to note that although the two groups did not differ in overall reading comprehension scores (Deaf: $M = 36.5$, SD $= 4.8$; Hearing: $M = 38.0$, SD $= 2.9$; $p = 0.19$, see Table 1), they did differ in morphological awareness ($p < 0.01$). Furthermore, the morphological awareness scores of the deaf group with high morphological awareness were lower than those of the hearing group with high morphological awareness (Deaf: $M = 33.9$, SD $= 3.5$; Hearing: $M = 39.4$, SD $= 2.7$; $p < 0.01$). This pattern indicates that the parafoveal preprocessing of morphological structure was not a result of high morphological awareness alone, but rather this

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pattern was a characteristic unique to the reading processes of skilled deaf readers. Morphological awareness, which can be a route through which deaf readers achieve word recognition in the absence of accessible input from phonology, may therefore be instrumental in helping deaf readers access the meaning of complex multimorphemic words. Strong morphological awareness skills could provide a boost to reading comprehension levels in complex contexts, helping deaf readers to access more advanced content. Morphological awareness has been shown to have a strong relationship with overall reading skill for deaf readers (Saunders et al., 2026) and predicts college-level English placement (Clark et al., 2011). Targeting this skill in reading interventions for developing deaf readers may provide an accessible tool for these readers to improve their vocabulary, comprehension, and eventual literacy outcomes.

In the current study, deaf readers' gaze durations on target words were numerically (though not significantly) longer than the hearing readers' gaze durations, in contrast to previous research finding overall shorter fixation durations for deaf readers (e.g., Traxler et al., 2021). This difference may be best explained by the nature of the target words in the current study. Word length and frequency have been shown to have larger effects on the skipping behaviors and gaze durations of deaf readers compared to hearing readers (Cooley et al., 2025). Specifically, deaf readers skip long words less often than their hearing peers and may also spend more time on them when they do fixate, indicating that these more "difficult" long words require more of their attentional resources. Morphologically complex words, which are more likely to be long and infrequent than simple words (English Lexicon Project; Balota et al., 2007), make up the majority of words encountered by skilled readers (Nagy & Anderson, 1984). Enhanced attention to morpho-orthographic structure in upcoming words could allow deaf readers to identify complex or infrequent words while they are still in the parafovea and determine that these words will require more attentional resources and longer fixations.

Limitations and future directions

One limitation of the current study is that morphological awareness and reading skill were correlated in our participant sample. This pattern aligns with previous research that morphological awareness supports overall reading ability (Deacon et al., 2014; Kotzer et al., 2021), and particularly for skilled deaf readers (Saunders et al., 2026). Although the two groups were matched on overall reading comprehension scores, decreasing the likelihood of group differences explained by reading skill, it is possible that the pattern of morphological preview benefits observed for the skilled deaf readers is driven by more general reading skill, as opposed to specifically morphological awareness.

Another possible concern regarding this study is that we did not replicate the findings of Dann et al. (2021), who found that hearing readers demonstrated a preview benefit from pseudomorphological structure in the parafovea. One speculative explanation for the difference between studies could be demographic variation in the participant samples. The participants in Dann et al. (2021) were all university students at the time of participation, whereas the participants in the current study ranged in age from 19 to 59 years and had a wide variety of

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occupations and educational backgrounds. Readers who are actively immersed in a higher education setting frequently encounter unfamiliar multimorphemic words and may be more attuned to morpho-orthographic cues compared to readers who are not college students. Although our sample of hearing readers scored highly on offline assessments of morphological awareness, their everyday reading habits likely require less attention to complex morphology in order to discern novel word meanings. Thus, their online eye movement behaviors during passive sentence reading may be less affected by morphological structure.

Previous research with prefixed preview words concluded that (hearing) readers of English did not preprocess morphological structure in the parafovea, likely because the most informative part of the preview (the stem) was too far from the central fixation to result in a preview benefit (Kambe, 2004; Dann et al., 2021). Deaf readers, however, who can process word information further into the periphery, may exhibit a parafoveal preview benefit from prefixed information, whereas hearing readers do not. Further research can reveal whether deaf readers exhibit morphological preview benefits for prefixed stimuli.

Conclusions

This study reported the first evidence of parafoveal preprocessing of morphological structure during sentence reading for deaf readers. We observed a larger preview benefit from pseudomorphological preview items than nonmorphological preview items that shared a root with the target word, but only for deaf readers with high morphological awareness. Segmentation of morphologically structured pseudoword cues facilitated access to a root word, and by extension, the real target word for these deaf readers. Hearing readers, regardless of morphological awareness ability, did not show a difference between pseudo and nonmorphological preview items, although both types of previews with a shared root elicited a preview benefit compared to an unrelated preview. This pattern of results suggests a unique relationship between morphological awareness and the initial stages of complex multimorphemic word recognition during sentence reading for skilled deaf readers.

Replication package. An OSF project containing the complete anonymized Rmarkdown project, stimuli, and data can be found at the following link: https://osf.io/wjca7/.

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