Derivational morphology affects children's word reading in English earlier than previously thought

Conventional wisdom suggests delaying instruction on derivational morphology of printed English words until perhaps grade four. However, younger children do encounter words with prefixes. As part of ongoing research into computer tutoring for reading, we wanted to use prefixes as teachable moments to help vocabulary learning, and study their effects. That led to two questions:
1. How often are prefixes reliable cues to meaning? 2. What is the effect of reliable prefixes on reading times?

First let us consider a prefix to be a morphological element coming before the root (cf. Matthews 2007); here we specifically look at derivational prefixes at the very beginning of a word. White, Sowell, and Yanigahara (1989) found that the 20 most common prefixes account for 97% of prefixed words in English printed school texts. The 9 most common account for 76% of all prefixed words, and Stahl and Nagy (2006) advise teaching those nine, which we analyze here:

un- *re-* *in-* (meaning not) *dis-* *en-* *non-* *in-* (meaning into) *over-* (meaning too much) *mis-*

Words such as *misspell* do contain prefixes; words such as *mister* appear to contain prefixes yet do not. For clarity, we call the initial part of the word – the candidate prefix – the head (*MISspell*, *MISter*) and the rest the tail (*misSPELL*, *misTER*). How often are these candidate prefixes, or heads, reliable cues to meaning? We measured reliability by overlap of the meaning of the head with words and phrases in the word's WordNet gloss, for words with tails of two or more letters (e.g. *misspell* and *mister* but not *mist*). The semantic reliability of these nine prefixes for the words in the American National Corpus turns out to be shockingly low – from as low as 4.85% for *dis-* and 5.78% for *en-* to as high as 22.04% for *in-* and 36.26% for *un-*. Thus only about one third of the time does *un-*, the most reliable, cue negation as part of word meaning (*unable*); surprisingly often it does not (*uncle*).

The extreme unreliability of these nine prefixes as semantic cues suggests that substantial knowledge is required to use them during reading. Such a finding would support the conventional delay in morphological instruction, and be reflected in how students at different reading levels read words with heads that are candidate prefixes, with morphology affecting reading time but only at higher reading levels. Our data, however, demonstrate that even at earlier reading levels, reading speed varies with the morphological status of the word. A detailed analysis explains this effect in terms of the morphological process of prefixation.

We looked at two factors: reliable head (see above), and reliable tail. We consider the tail a reliable cue if it is itself a word, to rule out cases such as *infidel* where *-fidel* may well be a cue to meaning but likely one not accessible to young children when encountered in print. We also consider the tail to be a reliable cue if it is an antonym of the original word, as in *unjustly*. We compared reading times for over two hundred children (212) on the best-case words (both head and tail reliable) vs. worst-case words (neither head nor tail reliable) using reading time data (milliseconds/letter) logged by a computer tutor that uses automatic speech recognition to listen to children read aloud. Words were shown in complete sentences as children read out loud from onscreen stories.

One might expect prefixes to speed up reading times for advanced readers, with no effect for less skilled readers. Instead, reading times were **slower** for best-case words than for worst-case words, a statistically significant 19% difference, and the effect is present for students of all reading levels: 115.7 ± 1.8 ms for 3783 best-case encounters vs. 97.1 ± 1.0 ms for 8013 worst-case encounters. (Here and throughout this abstract we use ± to denote a 95% confidence interval.) This is not a practice effect: for only first encounters, best-case reading times were still significantly slower by 17%. It is also not an effect of word length: for a matched length range (6-7 letters), best-case were still slower by 27%. Furthermore, for a matched word frequency range (10-500/million words), best-case were slower by 30%. Even with all three filters – practice, length, frequency – best-case words are still slower by 51%: 145.1 ± 5.7 ms for 507 best-case encounters vs. 96.3 ± 3.0 ms for 890 worst-case encounters.

What mechanism explains this persistent difference in reading speed? A number of theories are consistent with these data: perhaps *disagree* takes more processing steps than *distance* since it is processed as two morphemes, not one; perhaps *disagree* competes more with *agree* than *distance* does with *tance*, leading to slower reading times. Each explanation relies on children's use of the stem – that is, children being sensitive to morphology earlier than traditionally thought for printed text.

If so, there should be an effect of the components of the prefixation process on reading times. Besides prefix and stem meaning, prefixation leaves a third cue: evidence at their boundary. One way to look for effects of the boundary between prefix and stem is position-sensitive letter bigram frequency (PSLBGF), an established measure in psychology (e.g. Massaro 1980, ch. 5), which is the number of times a two letter combination occurs at a specific character position in a word (e.g. *nk* in *unknown* and *think* are counted differently: *nk* at position 2 vs. *nk* at position 3. Best-case words should (and do) show lower position-sensitive bigram letter frequencies (calculated from Balota et al. 2007) than worst-case words:

Best-case: 708.33 ± 5.3 Only tail reliable: 725.72 ± 10.6 Only head reliable: 723.05 ± 28.6 Worst-case: 879.45 ± 7.8

We added Low PSLBGF, that is, a word being in the bottom half with respect to position-sensitive letter bigram frequency, as a cue. When all three cues are present (head reliable, tail reliable, low PSLBGF) then reading time is slowest:

	Best-case	Only tail reliable	Only head reliable	Worst-case
Low PSLBGF	124.5 ± 2.4 ms	108.1 ± 3.2 ms	104.6 ± 4.7 ms	91.0 ± 1.8 ms
High PSLBGF	108.0 ± 5.1 ms	108.4 ± 3.4 ms	96.0 ± 5.4 ms	94.7 ± 1.3 ms

(The difference in the last column, for worst-case words, is statistically significant, but negligible at 3%.)

So, the largest effect for bigram frequency by position occurs when both the head and the tail are reliable.

Taking this result along with the head and tail cues having intermediate effects, the overall picture seems to be that the combination of cues (head, tail, boundary) produces the reading time effect – a fairly precise signature of a specifically morphological process.

In terms of linguistic research, these results highlight the value of empirically testing assumptions about the role that linguistic phenomena play in affecting human learning, as well as the benefits of using computer tutors as research instruments for the study of language, leveraging large sample sizes and detailed measurement. In terms of instructional consequences, children's early sensitivity to printed words' morphological structure, as demonstrated here, suggests that morphological instruction could be reconceptualized to take advantage of sensitivity to linguistic phenomena such as affix and root semantic reliability and morphological boundary effects.

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