

A promising new tool for literacy instruction: The morphological matrix

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Abstract

There is growing interest in the role that morphological knowledge plays in literacy acquisition, but there is no research comparing the efficacy of different forms of morphological instruction. Here we compare two methods of teaching English morphology in the context of a memory experiment when words were organized by affix during study (e.g., a list of words was presented that all share an affix, such as <doing>, <going>, <talking>, <walking>, etc.), or by base during study (e.g., a list of words was presented that all share a base, such as <doing>, <done>, <redo>, <undo>). We show that memory is better in both conditions compared to a control condition that does not highlight the morphological composition of words, and most importantly, show that studying words in a base-centric format improves memory further still. We argue that the morphological matrix that organizes words around a common base may provide an important new tool for literacy instruction.

A promising new tool for literacy instruction: The morphological matrix

Morphemes constitute the smallest units of meaning in an oral or written language, and in the case of English, include bases (e.g., <help>) that carry the main kernel of meaning in a word, and affixes (e.g. the prefix <un-> or the suffix <-ful>) that modify the meaning of the base (e.g., <unhelpful>). There is growing interest in the role that morphological knowledge plays in literacy acquisition in English. This interest is motivated by two general considerations. First, on a theoretical level, English is a morphophonemic language in which word spellings are organized around both phonology and morphology. Indeed, as we describe below, the English spelling system prioritizes the consistent spellings of morphemes over phonemes. This provides a rationale for teaching morphology along with phonology. Second, empirically, there is now ample evidence that morphological knowledge in young children predicts literacy outcomes (Duncan, 2018), and that morphological instruction improves literacy outcomes, especially for younger and less-abled readers (Goodwin & Ahn, 2010, 2013). Despite these theoretical and empirical considerations there is almost no research into how to best teach English morphology to children in order to improve reading, writing, and vocabulary (see Rastle, 2018).

Here we compare two approaches of teaching morphology in the context of a memory experiment. The first was designed to mirror the most common form of instruction, namely, an affix-centric approach that presents a set of unrelated base words that all share a given affix (e.g., presenting a list of words that all share the <-ing> affix such as <doing>, <going>, <talking>, <walking>, <playing>, etc.). The second was designed to mirror the base-centric approach used in Structured Word Inquiry or SWI (Bowers & Kirby, 2010; Bowers &

Bowers, 2017). Here a range of different affixes are combined with a given base to form a morphological family (e.g., presenting a set of words that share the same base <do> using a morphological matrix as in Figure 1). We show that memory is better in both conditions compared to a control condition that does not highlight the morphological composition of words, and importantly, demonstrate that studying words in a base-centric morphological matrix improves memory further still. We attribute these findings to the fact that memory, learning, and reasoning is best when information is encoded in an elaborative and organized manner (Bower, Clark, Lesgold, & Winzenz, 1969), and suggest that the morphological matrix may serve as an important tool for teaching morphology, and literacy more generally.

The paper is organized as follows. First, we briefly review the theoretical and empirical motivation for teaching morphology in order to improve various literacy outcomes including word naming, spelling, and vocabulary. Second, we review how word naming, spelling, and vocabulary are currently taught, and the role of morphological instruction in teaching these skills. Third, we report two experiments that compare two different methods for teaching morphology, and finally we consider the implications of our results for literacy instruction.

The theoretical motivation for teaching morphology

The main theoretical motivation for teaching morphology is simple: English has a morphophonemic spelling system that evolved to jointly represent units of meaning (morphemes and etymological markers) and sound (phonemes). Once this is understood, it becomes clear that English spelling system is well designed and has even been described as near “optimal” (Chomsky & Halle, 1968). This contrast with the common claim that the English spelling system follows an “alphabetic principle” in which letters represent meaning

via sounds, and where the grapheme-to-phoneme system is riddled with irregularities (for more discussion see Bowers & Bowers, 2018a).

To briefly illustrate the morphophonemic organization of English spellings, consider the morphological families formed from the bases <act>, <do> and <go> in Figure 1. The important point to note is that the spelling of the base remains consistent across all members of the morphological families even when changes in pronunciation are observed (e.g., *acting* vs. *action*; *do* vs. *does*; *go* vs. *gone*). The same applies to affixes. For example, consider the suffix <-ed> that is consistently spelled in *jumped*, *played*, and *painted* even though it is pronounced /t/, /d/ and /əd/, respectively. These examples are not cherry-picked; they are the norm. Rather than respecting an alphabetic principle, the English spelling system is better described as respecting a morphological principle that prioritizes the consistent spellings of morphemes over the consistent spelling of phonemes. Indeed, in order to spell morphemes in a consistent manner, it is necessary to have inconsistent (or perhaps a better term is ‘flexible’) grapheme-phoneme correspondences. Flexible grapheme-phoneme correspondences are a feature and not a bug of the English spelling system.

In addition to the role that morphemes play in constraining spelling and meaning, it is important to note how rich morphological families can be, as illustrated in Figure 2. In order for a word to be a member of a morphological family the word not only has to have a consistent spelling relationship with the base, it must also share a common sense and meaning that can be traced back through a common etymological history -- to the same historical root. In many cases the meaning of morphologically related words is transparent (e.g., <help>, <helpful> and <helpless>), while in some cases the meaning relation is less clear, but can still be traced and understood via etymological connections (e.g., <apt> from the Latin root *aptus* for “fit” can be linked to <adapt>, <aptitude>, and <adaptation>; <quest>

from the Latin root *quaerere* for “ask, seek, gain” can be linked to <question>, <conquest>, and <request>).

An appreciation of the underlying logic of the English writing system suggests a new possibility for reading instruction, namely, instruction can emphasize both the phonological and morphological regularities in word spellings. This contrasts to whole language that deemphasizes both of these sub-lexical regularities, and it contrasts to phonics instruction that selectively emphasizes the phonological regularities. Furthermore, as highlighted by Bowers and Bowers (2017), this hypothesis is well motivated given that learning and memory is best when information can be encoded in a meaningful and organized manner (e.g., Bower et al., 1969; Fiorella & Mayer, 2016). For example, Bower et al. (1969) carried out a memory experiment in which words were organized within a hierarchy that highlighted the meaningful relations amongst the words, as depicted in Figure 3. Memory was much better in this condition compared to a condition that did not highlight these relations. In a similar way, morphological matrices (as depicted in Figures 1 and 2) highlight the meaningful (and spelling) relations between words, raising the possibility that these matrices might be an effective way to study and learn morphological families of words.

The empirical motivation for morphological instruction

The linguistic analysis of the English writing system shows why morphology might be relevant to literacy instruction, and memory research provides some theoretical motivation for emphasizing the meaningful organization of words. But is there any empirical evidence that morphological knowledge and morphological instruction benefits literacy?

One line of research shows that untaught morphological knowledge is a good predictor of word naming, spelling, and vocabulary. For example, Kirby, Geier, and Deacon

(2009) found that morphological knowledge uniquely predicted reading speed, accuracy, decoding and comprehension in a sample of 182 Grade 3 students even after controlling for various other aspects like verbal and nonverbal intelligence, phonological awareness, naming speed and orthographic processing. Similarly, Deacon, Kirby and Casselman-Bell (2009) found that morphological knowledge measured in Grade 2 was able to explain approximately 8% of the variance of Grade 4 spelling even after controlling for other aspects like verbal and nonverbal intelligence, phonological awareness, verbal short-term memory, and rapid automatized naming. In the case of vocabulary, McBride-Chang and colleagues (2005) provided evidence that morphological knowledge was able to predict vocabulary learning in English-speaking kindergarten and Grade 2 students. They found that morphological measures uniquely contributed to an additional 10% of the variance in vocabulary in either group upon controlling statistically for other measures like those of reading, phonological awareness and naming speed. For a recent review of the impact of morphological awareness on literacy see Duncan (2018). Consistent with these findings, there is strong evidence that skilled reading in adults involves the morphological processing of complex word forms (Rastle, 2018).

With regards to instruction, it has long been argued that morphology should play a more prominent role (e.g., Bryant & Nunes, 2004; Henderson, 1984), but only in the past decade have a sufficient number of morphological intervention studies been carried out to support meta-analyses and systematic reviews. Goodwin and Ahn (2010) reported a meta-analysis that showed moderate and significant improvements on a range of outcomes for children with learning disabilities, and Goodwin and Ahn (2013) reported a meta-analysis that showed moderate and significant improvements on a range of outcomes for children from the general population. Interestingly, in the latter case, the greatest overall effect was obtained for children in preschool/early elementary grades ($d = 0.68$) compared to upper

elementary ($d = 0.29$) and middle school ($d = 0.34$), suggesting that morphological interventions should start early. Similarly, the meta-analysis of morphological instruction by Bowers et al. (2010) found the greatest benefits for younger and struggling readers, and systematic reviews by Reed (2008) and Carlisle (2010) found these groups benefited from morphological instruction as well. Most recently, in a meta-analysis of spelling interventions with children with dyslexia, morphological instruction was found to be effective, and just as effective as phonics overall in the early years of instruction (Galuschka et al., 2020). Interestingly, the effectiveness of phonics interventions decreased with the increasing severity of dyslexia whereas the efficacy morphological interventions increased with severity. Together, these findings suggest that morphology should be added to instruction, even from the start.

Common methods of reading, spelling and vocabulary instruction pay little or no attention to morphology

Given these compelling reasons to teach morphology, it is striking how rarely morphology plays a role in reading, spelling, and vocabulary instruction in the classroom, and how little consideration has been given to the question of how morphology should be taught. Consider the standard methods for teaching word reading, spelling and vocabulary.

With regards to reading and spelling, phonics and whole language (often rebranded as 'balanced literacy'; Moats, 2000) are the most common forms of early instruction. In the case of phonics, beginning instruction is focused on the mappings between graphemes and phonemes with minimal or no regard to the morphological composition of words. Some proponents of phonics argue that morphological instruction might be useful at later stages of instruction (e.g., Castles, Nation, Rastle, 2018), but little or no consideration is given to how to teach morphology at later stages (see below). In the case of whole language, children are

encouraged to read and write complete words in the context of meaningful passages, with less emphasis on mappings between grapheme and phonemes, and with grapheme-phoneme correspondences taught unsystematically (National Reading Panel, 2000). And again, the whole language approach includes little or no morphological instruction, and as far as we are aware, no suggestion that morphological instruction should be introduced in the later stages of literacy instruction. That is, the main two forms of initial reading and spelling instruction provide minimal/no morphological instruction and provide little guidance regarding how to teach morphology.

With regards to vocabulary instruction there is less consistent practice in schools and much less research. Indeed, the National Reading Panel (2000) noted that there was insufficient research to recommend one strategy over another. Since the National Reading Panel there has been more work, but there is still no widely adopted approach, and prominent proposals appear to be in conflict. For example, Biemiller et al. (Biemiller & Slonim, 2001; Biemiller & Boote, 2006) favored what might be described as a shallow but wide approach in which children are taught multiple words a day with the support of context (e.g., reading a story). An alternative approach that might be called a rich but narrow approach (e.g., Beck, McKeown, & Kucan, 2002; Blachowicz & Fisher, 2000) involves teaching fewer words in more detail using definitions with other active processing tasks. Neither of these approaches exploit the fact that words in morphological families share meaning. More generally, morphology continues to play a minor role in vocabulary instruction, and teachers themselves have little knowledge of how English spellings are organized around morphology (Washburn & Mulcahy, 2019).

How is morphology taught when it is taught?

Although the most common forms of reading, writing, and vocabulary instruction do not reference morphology at the start, morphology is often introduced in later stages (to varying extents). However, we are not aware of any research that has compared affix- and base-centric approaches, and in the school setting, teaching guidelines typically provide only vague descriptions of affix-centric approaches. For example, in the US, "The Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects" (National Governors Association, 2010) mentioned morphology twice, writing that Grade 4 and 5 students should "Use combined knowledge of all letter-sound correspondences, syllabication patterns, and morphology (e.g., roots and affixes) to read accurately unfamiliar multisyllabic words in context and out of context" (p 17), and with regards to vocabulary instruction writes "Use the most frequently occurring inflections and affixes (e.g., -ed, -s, re-, un-, pre-, -ful, -less) as a clue to the meaning of an unknown word." (p. 27). Similarly, in the UK National Curriculum (2013) for children in Key Stage 1-2 (ages 5 - 11), the main information regarding morphological instruction is found in a table in the document that provides only vague guidance for affix centric instruction. An affix-centric approach is likewise encouraged in countries such as Hong Kong, where teachers are advised to focus on affixes from Secondary levels 1-3 (H.K. Education Bureau, 2018), and in Singapore, where it is recommended that the concept of affixes be introduced from Primary 1 onwards (S.G. Ministry of Education, 2010). In all cases, English teachers are left to their own devices to teach morphology as they see fit, with only general guidance in affix-centric instruction.

As far as we are aware, morphological matrices that provide a tool for the base-centric approach (as in Figures 1 and 2) have only been used in the *structured word inquiry* or SWI method of literacy instruction (Bowers & Kiby, 2010; Devonshire, & Fluck, 2010;

Devonshire, Morris, & Fluck, 2013). A morphological matrix must have one base that is involved in constructing any word from that matrix. The matrix is “read” from left to right. Cells before and/or after that central base contain morphemes which can be combined to construct words. These cells contain the full written form of these morphemes without suffixing changes and any spelling changes are marked in word sums for the individual words reflected in the matrix. Vertical lines mark morphemic boundaries and horizontal lines cannot be crossed in the construction of a word. Note, SWI uses a range of tools to teach the interrelation between morphology, phonology and etymology (e.g., Bowers & Bowers, 2017, 2018), but here we are only concerned with the efficacy of the morphological matrix as a tool to teach morphology in a base-centric manner.

The Present Study

The present study takes a first step in exploring how to design morphological instruction by comparing how well affix-centric and base-centric study conditions support later free recall in two memory experiments. Participants studied a set of morphologically related words for a subsequent memory task when groups of words were organized by a common affix (standard method of instruction) or base (the morphological matrix used in structured word inquiry), or when randomly intermixed with no reference to morphology (control condition). Given that learning and memory is best when information can be encoded in a meaningful and organized manner (Bower et al., 1969), we predicted that memory performance would be best in the two morphological conditions. The critical question is whether organizing words by affix or base leads to better memory performance.

Experiment 1

Method and Results

Participants. A total of sixty-two English-speaking participants (mean age = 21.3, SD = 2.43; 30.6% were males) from the University of Bristol participated for either course credit or payment. All participants had normal language abilities. Participation occurred with informed consent and the experimental protocols were approved by the Institutional Review Board.

Design and Materials. Participants were assigned to one of three study conditions: A control condition (n = 21) in which words were presented in lists without any form of organization, an affix-centric condition (n = 20) in which words with different bases were grouped by a common affix, or a base-centric condition (n = 21) in which a morphological family of words that all shared a common base were presented in a morphological matrix much like that used in SWI. We selected 40 morphologically complex words constructed from 10 base words and 10 affixes, half of which comprised either a base word combined with a prefix (e.g., <un> + <cover> → <uncover>), and the other half, a base word combined with a suffix (e.g., <employ> + <s> → <employs>). Affixes were paired to some words but not others so that participants had to remember the precise pairings. In the two morphological conditions words were grouped either by affix or base to form lists or matrices of 4 words. In the control condition, words were organized lists of 4 randomly selected words from the pool of 40 words. In total, 10 stimulus lists (each composed of four words) were created for each condition and all groups received the same items, just organized differently. For more details regarding how words were organized in the affix- and base-centric conditions please refer to Appendix 1. Each participant studied and recalled the 40 words twice.

Procedure. Participants sat in front of a computer and were tested in groups of 1-6 with stimuli presented using PsychoPy 3 (Peirce, Gray, Simpson, MacAskill, Höchenberger, Sogo, Kastman & Lindeløv, 2019). Participants were instructed to remember the words presented on the screen. A practice session was conducted to familiarize participants with the general flow of the experiment. Each participant was given 3 seconds to remember each word, with each stimulus list or matrix presented for a total of 12 seconds. The order in which the lists and matrices were presented was randomized. After all lists or matrices were presented participants wrote down as many words that they could remember on a blank slip of paper. Participants were free to write down the words in any format that they chose, and while not explicitly told to do so, some chose to represent their answers in the matrices that had previously been presented. This slip of paper was then collected from the participants. The experiment was then repeated using the same materials and procedure without the practice session. This provided two sets of recall data in each condition, and provided an assessment of whether the different methods of organizing words support greater or smaller differences with increased practice (similar to the procedure by Bower et al., 1969 that highlighted the benefits of organizing materials for memory performance, especially with repetition).

Results and Discussion.

The mean recall scores in the three study conditions and two recall tests are summarized in Figure 4. A 3 x 2 between-within mixed ANOVA was conducted on the number of words correctly recalled, with Study Condition as the between factor (Control, Affix-centric and Base-centric) and Test Iteration as the within factor (Memory Test 1, Memory Test 2). Only words from the study phase that were correctly spelt were considered correct (erroneously recalled words and those that were misspelt were coded as incorrect).

Not surprisingly, a main effect of test iteration was observed, with participants more likely to recall more words in the second compared to the first test, $F(1, 59) = 124.32$, $MSE = 538.12$, $p < .001$. More importantly, we observed a main effect of study condition, $F(2, 59) = 16.37$, $MSE = 314.85$ $p < .001$, with both the affix-centric (24.2% recall) and base-centric (29.0% recall) conditions supporting better recall than the control condition (17.6% recall). We also observed a significant interaction between study condition and test iteration, $F(2, 59) = 6.29$, $MSE = 27.23$, $p < .005$, reflecting the greater memory performance in the base-centric condition in the second memory test. The planned comparison between the affix- and base-centric study conditions was significant, $t(39) = 2.17$, $p = .036$, corresponding to a medium sized effect (Cohen's $d = 0.68$), with a null effect observed in memory test 1, $t(39) = .679$, $p > .05$, and a robust effect in memory test 2, $t(39) = 2.96$, $p = .005$. Together these findings highlight the value of organizing words into their morphological components, and the added value of presenting words in a morphological matrix in order to encourage a base-centric approach to studying morphological families.

The pattern of errors that is summarized in Table 1 also highlight the impact of the morphological study conditions. We categorized errors into four sub-categories: Recombined Errors that reflected the correct recall of an affix and a base but recombining them into a non-studied word, partial errors that reflected the correct recall of an affix or a base but not both (i.e., a correctly recalled base or affix is paired with an affix or base outside of the study list), unrelated errors that reflected recalled words that included neither a studied based or affix, and spelling errors. All error proportions were calculated with the total number of words presented as the denominator. As is clear from Table 1, the rate of recombined errors was much greater in the two morphological study conditions, leading to somewhat higher error rates in the two morphological conditions. Note, these recombined errors reveal that the participants were using morphology to inform their memory responses. In the context of a

memory experiment, the increase in recombined errors might be considered a negative. But in the context of assessing the overall impact of the morphological encoding conditions on memory and learning more generally (where all morphological forms should be learned, not just studied words), these errors might be considered further evidence that the two morphological study conditions are more effective (reflecting the learning of new morphologically complex words). In Experiment 2 we redesigned the study lists in an attempt to reduce the recombined errors in order to get a more straightforward assessment of the benefits of encoding words in the morphological conditions.

Experiment 2

In order to reduce the incidence of errors we developed a new set of words in which eight bases and eight affixes were factorially combined (all affix-base combinations were studied), making a total of 64 words to recall. In this way, if a participant remembers a base and an affix correctly, he or she will not incorrectly combine them to produce a recombined error. Again, we anticipate that participants will use their morphological knowledge to improve memory performance in the two morphology conditions, and the critical question is whether the base-centric study condition improves memory performance more than an affix-centric condition.

Method and Results

Participants. A total of sixty-four English-speaking participants (mean age = 24; 28% were males) from the University of Bristol participated for either course credit or payment. This new set of participants were drawn from the same pool of participants as Experiment 1. Once again participants were assigned to either the control condition ($n = 20$), the affix-centric condition ($n = 22$) or the base-centric condition ($n = 22$).

Design and Materials. A total of 8 base words and 8 affixes were chosen, and all the base words chosen were able to form legal permutations of morphologically complex words with all affixes. In total, 64 morphologically complex words were formed, half of which comprised either a base word combined with a prefix (e.g., <un> + <employ> → <unemploy>), and the other half, a base word combined with a suffix (e.g., <employ> + <s> → <employs>). These words were grouped either by affixes (for the affix-centric condition) or their bases (for the base-centric condition) to form lists or matrices of 8 words each. Lists of 8 randomly selected words from the pool of 64 words were also created for the control condition. In total, 8 lists or matrices were created for each condition. For full details of the lists, matrices and words used, please refer to Appendix 2.

Procedure. As above, participants were seated in front of a computer, tested in groups of 1 to 6, and asked to remember words that were to be presented to them on the screen. A practice session was conducted to familiarize participants with the general flow of the experiment. Each participant was given 3 seconds to remember each word, with each stimulus list or matrix presented for a total of 24 seconds. The order in which the lists and matrices were presented was randomized. After all lists or matrices have been presented, participants were asked to write down as many words that they could remember on a piece of paper, which was collected from the participants once they were done with this portion of the experiment. The experiment was then repeated using the same materials and procedures, without the practice session.

Results and Discussion

As before, only words from the study phase that were correctly spelt were considered correct, and the mean recall scores across conditions are summarized in Figure 5. A 3 x 2 between-within mixed ANOVA showed a main effect of test iteration, with participants

performing better in the second compared to the first test, $F(1, 61) = 92.94$, $MSE = 4029.87$, $p < .001$, and a main effect of study condition, $F(2, 61) = 41.609$, $MSE = 8452.22$, $p < .001$, with both the affix-centric (58.7% recall), and base-centric (71.3% recall) condition supporting better recall compared to the control condition (28.0% recall). And again, a significant interaction was also found between test iteration and study condition, $F(2, 61) = 6.72$, $MSE = 291.38$, $p < .005$, reflecting the greater improvement in the base-centric compared to affix-centric conditions in the second memory test. The planned comparison between the affix- and base-centric conditions was again significant, $t(42) = 2.93$, $p = .005$, corresponding to a large effect size (Cohen's $d = 0.88$), with the contrast between the base- and affix-centric conditions approaching significance in memory test 1, $t(42) = 1.67$, $p = .102$, and robust in memory test 2, $t(42) = 2.559$, $p = 0.014$.

Furthermore, as expected, the new design of the study lists (fully crossing the base and affix conditions) eliminated the recombined errors in the two morphological conditions, resulting in much reduced overall error rates in the two morphological conditions. Indeed, the overall recall performance was much higher in Experiment 2 (52.5%) compared to Experiment 1 (28.3%), with recall rates most improved in the two morphological conditions, especially so in the base-centric morphological matrix condition.

General Discussion

In two experiments we found that memory for a set of morphologically related words was better when the study conditions highlighted the morphological composition of words compared to a control condition that ignored this structure. The critical finding, however, is that memory was best when words were studied using morphological matrices that organized words into morphological families. As noted above, morphological instruction plays a minor role (at best) in literacy lessons at present, and when morphology is considered, affix-centric

approaches tend to be adopted. As far as we are aware, there is no mention of morphological matrices in any government curriculum on literacy instruction, and despite the use of the matrix of in Marcia Henry's highly-cited textbook "Unlocking Literacy" (2003/2010), we are not aware of any other depictions of the morphological matrix in the research literature other than a handful of articles describing the structured word inquiry method (e.g., Bowers & Kirby, 2010; Bowers & Bowers, 2017, 2018a). Our findings are important because they motivate the introduction of a new tool for morphological instruction with relevance to teaching spelling, vocabulary, and word naming.

Why did the morphological matrices improve memory outcomes? We take our findings to be closely related to the earlier finding from Bower et al. (1969) who observed improved memory when a set of semantically related words were organized in a semantic hierarchy. They argued that this organization helped participants generate a retrieval plan for reconstructing items from memory, and morphological matrices may have provided a similar benefit to memory retrieval strategies in our experiments. In addition, our findings are closely related to "generative learning" that involves organizing and integrating to-be-learned information with prior knowledge in order to improve the initial encoding of memories (for review see Fiorella & Mayer, 2016). One common tool for generative learning that is especially relevant is a *graphic organizer* in which key concepts are arranged in meaningful format such as a matrix. Indeed, of all the generative learning strategies reviewed by Firella and Mayer (2016), a matrix organizer was found to be the most effective with a median effect of $d = 1.07$ across eight studies. Whether our morphological matrices improved memory performance by improving encoding or retrieval (or both) is an interesting question, but in either case, our findings with morphological matrices are consistent with a large literature in cognitive science and education research.

Of course, there is a large gulf between teaching morphology to children in the classroom and our memory experiment carried out on undergraduate students. Nevertheless, we would argue that the benefits observed in the morphological matrix condition reflect a fundamental property of memory and learning that applies to both adults and children; namely, it helps to study and recall information in a meaningful and organized manner. And indeed, graphic organizers have been shown to be useful in a classroom setting in grade 4 for learning material in a social studies lesson (Ponce, Mayer, López, & Loyola, 2018), and reading comprehension and writing in grade four, six and eight students (Ponce, Mayer, & Lopez, 2013).

More directly relevant, there is some preliminary evidence that the morphological matrix does help literacy instruction in children. For example, Bowers and Kirby (2010) reported that a structured word inquiry study that included the morphological matrix improved vocabulary learning in grade 4 and 5 students. Similarly, Devonshire and Fluck (2010) showed benefits in spelling Year 4 and 5 students in England (ranging from age 7-9) following an intervention that included morphological matrices, and Devonshire et al. (2013) reported benefits in spelling and naming aloud words in a Year 1 and 2 (children aged between 5-7) using matrices. These studies used a range of additional tools in addition to the morphological matrices, and the current study suggest that the matrix per se. played a role in these results.

Another reason to think that morphological matrices may provide an important tool for literacy instruction is that they can be used to explicitly teach a wide variety of literacy skills, including grapheme-phoneme correspondences, spelling, and vocabulary. The value of matrices for teaching spelling and vocabulary is obvious: Words are explicitly organized in groups that share spellings and meanings, and highlighting this structure improves memory

(as we have shown). But matrices might also improve the teaching of grapheme-phoneme correspondences. Similar to analytic phonics, children can be taught to break down a set of related words into their constituent graphemes and phonemes, but because words are organized into morphological families, the logic of the grapheme-phoneme correspondences can be made clearer. For example, consider the word <react>. Is the <ea> letter sequence a digraph corresponding to a single phoneme (pronounced /i:/) or two distinct graphemes <e> and <a> corresponding to two different phonemes? Morphology clarifies the phonology: The word <react> has the morphological structure <re + act> and this rules out <ea> as a digraph because graphemes never cross morphemic boundaries. Similarly, morphology explains why the words <dogs> and <cats> contain the same <s> grapheme despite the different pronunciations (/z/ and /s/, respectively). For more detail see Bowers and Bowers (2018a).

Importantly, the matrix can be used to teach various forms of literacy skills at the same time, and consequently, children may benefit from interactions between these skills. And indeed, there is growing empirical evidence that various literacy skills do interact. For example, vocabulary knowledge is important for reading comprehension (e.g., Valentini, Ricketts, Pye, & Houston-Price, 2018), spelling knowledge is associated with better word naming (Ouellette, Martin-Chang, & Rossi, 2017), and morphological instruction improves phonological awareness and word decoding (Goodwin and Ahn, 2013). Furthermore, on a theoretical level, Perfetti (2007) highlighted the importance of the interrelation between pronunciations, orthography and semantics of words for “constituent binding” in his lexical quality hypothesis. For example, Perfetti (2007) wrote, “Bindings are connections that secure coherence among the constituents, the orthographic, phonological, and semantic representations, which together are the word’s identity. The binding feature is not independent but rather a consequence of the orthographic, phonological and semantic constituents becoming well specified in association with another constituent” (pp. 360-361).

Building on this work, Kirby and Bowers (2017) argued that morphology acts as a “binding agent” as it is the one aspect of the language that reflects all the features of lexical quality, that is, morphemes have pronunciations, spellings and carry meaning.

Consider again Figure 1 for an illustration of how morphological matrices can be used to draw explicit attention to the interrelation of phonology, orthography and semantics. We can use this matrix to help learners *understand* why the word “action” is spelled with a <t>, not an <sh> for the /ʃ/ phoneme, as only the <t> can represent that phoneme and the /t/ in the morphological relatives such as <act> and <acting>. That is, the grapheme <t> is mapped onto the /ʃ/ phoneme so that the meaningfully related words <act> and <acting> have consistent spellings of their shared base. See a video at this link (<https://tinyurl.com/does-matrix>) to see an instructor using a matrix to teach a class about the spelling of <does> that puts these ideas into practice. To summarize, morphological matrices not only provide a promising tool for teaching morphology per se., they provide a tool for explicitly teaching the interrelation of meaning, spelling, and pronunciation, and this may be useful for learning better quality lexical representations.

Is the morphological matrix a general tool that can be applied to most words? In our studies we built morphological families from a word that can stand on its own as the base (e.g., <count>). But the full richness and ubiquity of morphological families becomes apparent when considering the many “bound bases” (like <rupt> or <struct>) that do not form words unless they are bound to at least one other morpheme (e.g., dis + rupt → disrupt; bank + rupt → bankrupt; in + struct → instruct; struct + ure → structure). By considering both bound and free morphemes, the morphological matrices can be used to teach virtually all words. This includes the words that beginning readers need to learn given that over 50% of words in children’s books are morphologically complex (Bowers & Bowers, 2018b).

Our findings provide evidence that morphological matrices can be used to improve memory and learning of morphologically related words in adults, and a variety of research suggest that morphological instruction is important to reading instruction in children. An important question for further research is at what age morphological matrices can be effectively introduced to children. This relates to a more general question as to when any form of morphological instruction should be introduced. As noted above, it is often argued that morphological instruction should be introduced after phonics instruction (Castles et al., 2018), based on the assumption that it is too difficult for younger children. But there no empirical evidence for this claim (see Bowers & Bowers, 2018b), and there are some preliminary findings suggesting that morphological instruction is appropriate from the start. For example, various meta-analyses and reviews have found that morphological interventions are most effective with younger readers (Goodwin & Ahn, 2010, 2013), and the Devonshire et al. (2013) study that reported benefits in spelling and naming aloud words in a Year 1 and 2 (children aged between 5-7) in an intervention study that used morphological matrices, and Anderson, Whiting, P.N. Bowers, and Venable (2019) have detailed how morphological matrices can be used in initial reading instruction. But even if future research shows that morphological instruction should be delayed for a few years after the start of instruction, it is still important to know how to best teach morphology to older children. Our findings suggest that the morphological matrix may be a useful tool for morphological instruction, and we hope our findings motivate further research with children, and perhaps consider Structured Word Inquiry that uses the morphological matrix along with various other tools.

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Figure 1

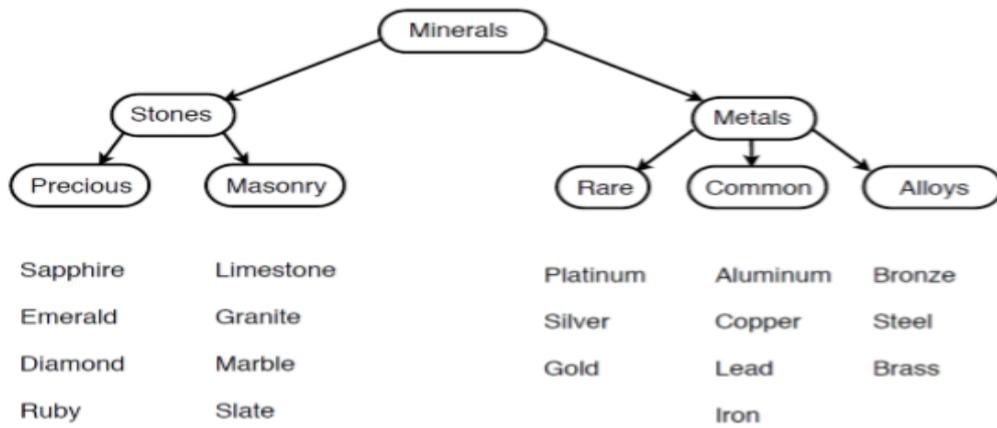
Morphological matrices for the bases <act>, do and <go>.

in re	act	ing ion or	
		ive	ly

do	es
	ing
	ne

go	es
	ing
	ne

Figure 2



con in re un	quest <i>"ask, seek, gain"</i>	ed s	
		ion	able ably er ing

ad	apt	ability able ed ing ly s		
		ate	ion	s
		er or	s	
		ite	ude	

Figure 3

Figure 4. Mean recall scores for each group in each Memory Test for Experiment 1 (error bars indicate 1 standard error above and below the mean)

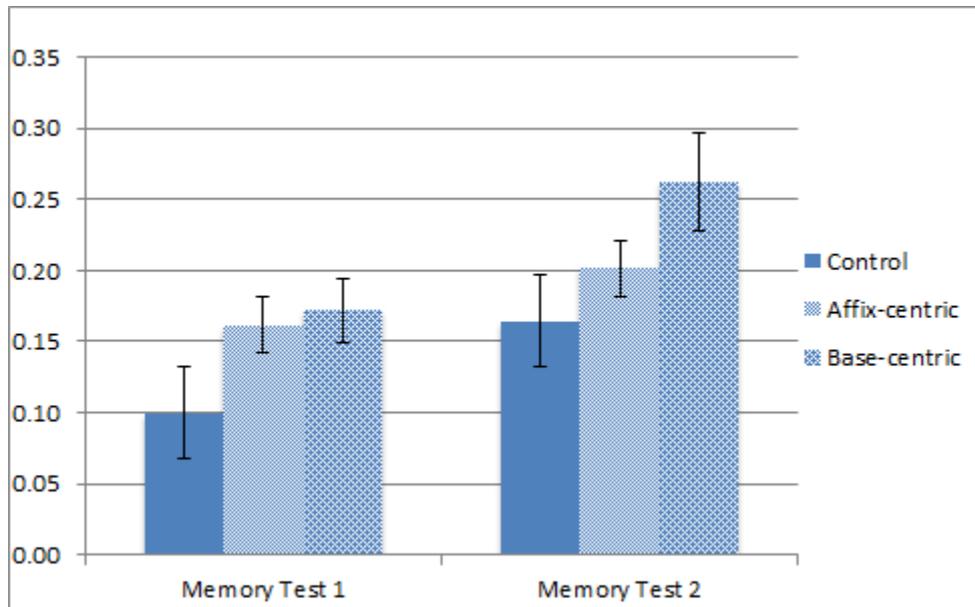


Figure 5. Mean recall scores for each group in each Memory Test for Experiment 1-2 (error bars indicate 1 standard error above and below the mean)

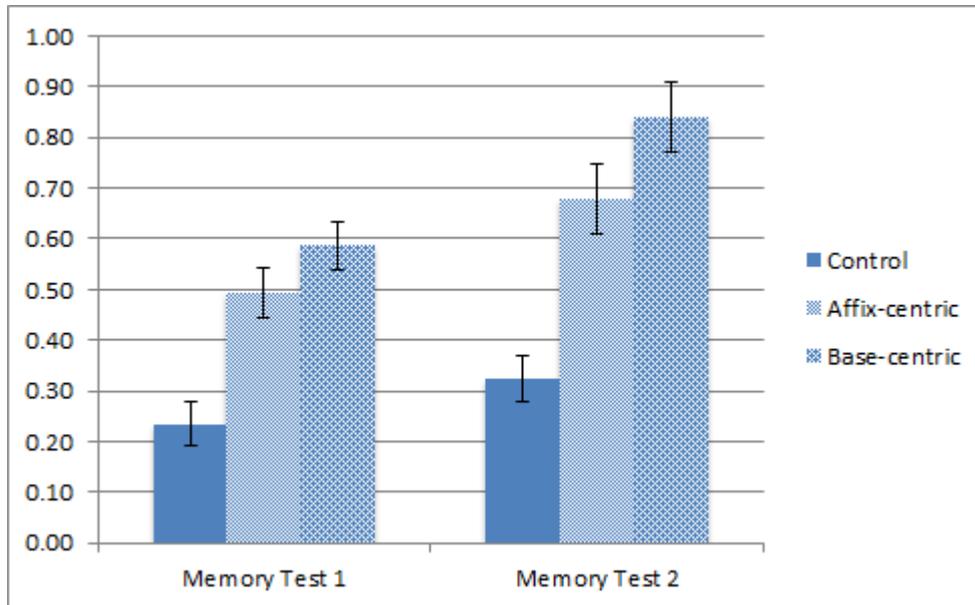


Table 1 Error type (%) across study conditions for Experiment 1.**Test 1**

Condition	Overall	Recombined	Partial	Unrelated	Spelling
Control	10.71	3.87	0.50	6.35	0.00
Affix-Centric	13.66	12.04	0.12	1.50	0.00
Base-Centric	13.19	11.92	0.23	1.04	0.00

Test 2

Condition	Overall	Recombined	Partial	Unrelated	Spelling
Control	11.41	5.46	0.30	5.56	0.10
Affix-Centric	14.47	13.89	0.23	0.35	0.00
Base-Centric	16.44	14.35	0.35	1.74	0.00

Table 2 Error type (%) across study conditions for Experiment 2.**Test 1**

Condition	Overall	Recombined	Partial	Unrelated	Spelling
Control	7.99%	0.00%	0.23%	7.70%	0.06%
Affix-centric	4.33%	0.00%	0.36%	3.05%	0.92%
Base-centric	2.58%	0.00%	1.14%	1.20%	0.24%

Test 2

Condition	Test 2	Recombined	Partial	Unrelated	Spelling
Control	8.28%	0.00%	1.10%	6.77%	0.41%
Affix-centric	3.69%	0.00%	0.50%	2.06%	1.14%
Base-centric	1.50%	0.00%	0.48%	0.30%	0.72%

Appendix 1 Stimuli for Experiment 1

Affix-centric condition

dis-	charge
	arm
	count
	employ

over-	cover
	act
	take
	employ

charge	-ing
arm	
act	
mount	

employ	-er
take	
write	
count	

re-	charge
	mount
	act
	balance

cover	-able
take	
write	
charge	

un-	cover
	arm
	write
	mount

arm	-ed
count	
mount	
balance	

mis-	count
	balance
	take
	write

cover	-s
employ	
balance	
act	

Base-centric condition

dis-	charge	-ing
re-		-able

un-	write	-er
mis-		-able

dis-	arm	-ing
un-		-ed

re-	act	-s
over-		-ing

dis-	count	-ed
mis-		-er

un-	mount	-ing
re-		-ed

un-	cover	-able
over-		-s

re-	balance	-s
mis-		-ed

dis-	employ	-s
over-		-er

mis-	take	-able
over-		-er

Appendix 2 Stimuli for Experiment 2

Affix-centric condition

dis-	employ
	value
	use
	mount
	cover
	place
	balance
	arm

re-	employ
	value
	use
	mount
	cover
	place
	balance
	arm

un-	employ
	valued
	use
	mount
	cover
	place
	balance
	arm

over-	employ
	value
	use
	mount
	cover
	place
	balance
	arm

employ	-ed
value	
use	
mount	
cover	
place	
balance	
arm	

employ	-s
value	
use	
mount	
cover	
place	
balance	
arm	

employ	-ing
value	
use	
mount	
cover	
place	
balance	
arm	

employ	-able
value	
use	
mount	
cover	
place	
balance	
arm	

Base-centric condition

dis-	employ	-ed
un-		-ing
re-		-s
over-		-able

dis-	place	-ed
un-		-ing
re-		-s
over-		-able

dis-	value	-ed
un-		-ing
re-		-s
over-		-able

dis-	balance	-ed
un-		-ing
re-		-s
over-		-able

dis-	use	-ed
un-		-ing
re-		-s
over-		-able

dis-	arm	-ed
un-		-ing
re-		-s
over-		-able

dis-	mount	-ed
un-		-ing
re-		-s
over-		-able

dis-	cover	-ed
un-		-ing
re-		-s
over-		-able