Does Automatic Morphological Processing Uniquely Contribute to the Reading Abilities of Middle School Students?

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Purpose: Morphological processing is theorized to contribute to skilled reading via the processing of high-level regularities (e.g., semantics). However, morphemes also may contribute to skilled reading via relatively low-level regularities: orthography and phonology. Evidence suggests that middle school marks the shift from effortful use of knowledge of morphological structure during word reading to its automatic activation, thus supporting the development of reading fluency and comprehension. Consequently, this study asked whether automatic morphological processing contributes unique variance to these reading outcomes in middle school students.

Method: Participants were 80 seventh- and eighth-grade students (*n* female = 42, *n* male = 38; mean age = 12.76 years). Four assessments measured decoding, oral reading fluency, and comprehension. Four computer-administered experimental tasks (each with a masked and unmasked version) indexed automaticity and knowledge in reading morphologically complex and simple words. Three analysis approaches were used in a conceptual replication of previous studies (Roembke et al., 2019; 2021): mixed ANOVAs, commonality analyses, and hierarchical regressions.

Results: Only automaticity with morphologically complex words contributed unique variance to comprehension, and it also contributed unique variance to fluency. This was shown on a task that required the mapping of morpho-orthographic to morpho-phonological regularities. Automaticity with morphologically simple words most consistently contributed unique variance to decoding and fluency.

Conclusions: Results suggest that middle school students automatically apply morpho-orthographic to morpho-phonological regularities to support fluency and comprehension. However, there was no evidence that they automatically map morpho-orthographic to morpho-semantic regularities to uniquely influence these outcomes.

In middle school, academic success depends on the ability to learn content by reading (O’Connor et al., 2017; Reed et al., 2017). Yet, many middle school students have reading difficulties that hinder their ability to learn from text (National Center for Education Statistics, 2025). These older students do not just struggle with higher-level skills (e.g., reading comprehension)—they often have word reading and fluency challenges that hinder comprehension (Cirino et al., 2013). Critically, the words they encounter at these ages are likely to be more structurally complex than those encountered in primary grades (Hiebert et al., 2018). Thus, to support academic success in middle school, we need research on factors that support not only comprehension, but also decoding and fluent reading.

The Importance of Automaticity

One such factor, automatic word recognition, has long been identified as theoretically important to reading fluency and comprehension (e.g., LaBerge & Samuels, 1974; Perfetti, 1985). Automatic word reading is both rapid and effortless (Logan, 1997) and is thought to contribute to fluency and comprehension by freeing up cognitive resources needed to make meaning from text (LaBerge & Samuels, 1974; Perfetti, 1985). It differs from knowledge of a word, such as knowing the relevant grapheme-phoneme correspondences or the whole wordform or its meaning (Roembke et al., 2019). Automaticity may be particularly important for older readers, who often have mastered enough words and/or grapheme-phoneme correspondences to read words accurately. They may have the knowledge but lack the skill to effortlessly apply this knowledge.

The term *automaticity* is sometimes used interchangeably with *reading speed* and operationalized as such. Although automatic word reading certainly is fast, simply measuring reading rate may not isolate the efficiency of specifically word recognition processes. That is, reading speed measures may confound automaticity in word reading with other related variables, such as the speed of general decision-making or the rate at which students articulate speech (Förster et al., 2003; Parrila et al., 2004). Speeded measures may also be susceptible to the speed/accuracy tradeoff—students can either read very quickly to achieve a high rate or slow their reading to improve accuracy (Samuels, 1979). Critically, individuals vary in where they position themselves on the tradeoff (Lohman, 1989)—this is another potential confound of purely rate-based measures. Therefore, in the present study, *automaticity* refers to the automatic application of cognitive word reading processes, rather than reading speed (e.g., Roembke et al., 2019, 2021).

Some of these concerns have been addressed by recent work that has employed a novel backward masking paradigm (Roembke et al., 2019, 2021). These studies differentiate *knowledge* of a word (knowing grapheme-phoneme correspondences or the wordform and its meaning) from *automaticity* (how rapidly knowledge is deployed). In the backward masking paradigm, a word is briefly presented and then covered with a visual mask. The participant produces a response related to the word (e.g., select the most representative picture). Consequently, phonological and semantic information must be automatically activated while the visual input is available for a correct response (Breitmeyer & Ogmen, 2000). Critically, after the mask, the response is untimed, meaning that speed of decision-making, speaking rate, and the speed accuracy/tradeoff are not major factors in performance. In contrast, in unmasked task versions, the visual input remains, allowing participants to apply phonological and semantic information and precluding the need to automatically activate this information, 1980). Thus, masked versions of a task index automaticity, while unmasked versions capture knowledge (Roembke et al., 2019, 2021). Intriguingly, masking can be applied to many tasks (e.g., reading words aloud, matching words to pictures). Consequently, it can potentially tap automaticity in multiple word-level reading processes and pathways.

Two previous studies implemented this paradigm across several tasks to understand the role of automaticity in middle school students with below-average to average reading abilities (Roembke et al., 2019, 2021). Overall accuracy showed a consistent masking decrement across experimental tasks (i.e., performance was lower in masked than unmasked versions). In both studies, unmasked performance (knowledge) only accounted for unique variance in decoding outcomes. However, masked performance (automaticity) uniquely predicted oral reading fluency over and above unmasked performance (knowledge). Furthermore, Roembke et al. (2021) found that automaticity in multisyllabic word reading is even more diagnostic. It predicted *decoding* and *reading comprehension* (unlike the same tasks with monosyllabic words) and was associated with a larger amount of unique variance in reading fluency than monosyllabic words. The strong findings with multisyllabic words raise the possibility that students have knowledge of some structures in multisyllabic words that they rapidly activate to contribute to automatic word recognition, thus supporting fluent reading and comprehension. This study focuses on one such source of structure: morphemes.

Morphological Processing and Reading

Morphological ability is any ability that involves using morphemes (i.e., the smallest units of meaning in words) to understand or produce oral or written language. Morphemes include stems (e.g., *happy*, *destroy*), affixes (prefixes and suffixes as in *<u>un</u>happy*, or *destroy<u>ed</u>*), roots (e.g., *struct*, *gen*), and combining forms (e.g., *photo*, *therm*). These word parts may be particularly critical to success across the middle school curriculum—academic texts often contain multisyllabic words composed of multiple morphemes (Hiebert et al., 2018; Nippold & Sun, 2008). This study concerns morphological *processing*, a type of morphological ability in which students use morphological structure in an implicit way to read words. Importantly, morphological structure offers rich sources of information that can support reading, both high-level (e.g., semantic, syntactic) and low-level (e.g., frequent orthographic chunks; Rastle, 2019).

First, morphemes provide semantic and syntactic information that fosters vocabulary development, which, in turn, supports comprehension (Goodwin & Cho, 2016; Goodwin et al., 2017; McCutchen & Logan, 2011). Most prior studies of morphological ability and reading in middle school students have focused on the role of morphological *awareness* (the explicit recognition and manipulation of morphemes) in comprehension. These suggest morphological awareness contributes unique variance to middle school students' reading comprehension beyond other reading and language abilities (e.g., Goodwin et al., 2020; James et al., 2020). Thus, middle school students use morpho-semantic and morpho-syntactic information to comprehend text. However, automaticity is often defined as happening without awareness, suggesting that morphological awareness may not be the whole story in automatic word reading.

Second, morphemes provide orthographic regularities that may function as chunks to support efficient word processing. There is a robust evidentiary basis for one aspect of morphological processing, *morphological decomposition*, in which words are decomposed, or segmented, into their constituent morpho-orthographic units before being mapped to meaning (Rastle, 2019). Morphological processing appears to be a key contributor to efficient word reading exhibited by skilled adult readers (Amenta & Crepaldi, 2012; Beyersmann et al., 2012; Rastle et al., 2004). But how does this develop?

According to most theories of reading (e.g., Coltheart et al., 2001; Harm & Seidenberg, 2004), there are two pathways for visual word recognition. In the first (and indirect) pathway, readers map orthography to phonology before retrieving the lexical entry or the meaning of a word (*orthography→phonology→semantics [O→P→S]*). In the second, orthography is mapped directly to meaning (*orthography→semantics [O→S]*). Morphological processing may support automatic word reading by contributing to the acquisition and rapid application of morphological structures in both pathways.

First, the chunking of morpho-orthographic units may lead to more efficient processing in the *O→P→S* pathway than relying on letter-sound mappings or syllables (Ehri, 2005). That is, even if a string like -AGE is not recognized as a meaningful unit (meaning "the state of" and serving a grammatical function of forming nouns), those letters occur together frequently and almost always make the sounds /ɪ/ + /dʒ/, enabling them to support more rapid mapping of orthography to phonology.

Second, chunking morpho-orthographic units may support the acquisition of morpho-semantic regularities used to directly map orthography to meaning, thus developing the more direct (and more efficient) pathway primarily used by skilled readers (Rastle & Davis, 2008). That is, the direct *O→S* pathway is often described as arbitrary in the sense that words that are spelled similarly do not usually have similar meanings. This large set of arbitrary mappings is difficult to acquire and generalize to new words (hence the benefit for decoding which emphasizes the simpler and generalizable *O→P* pathway). However, morphological structure can offset this—words that are spelled similarly *because of morphology* have more similar meanings. This may be particularly important for supporting multisyllabic word reading, which is critical to academic success in the secondary grades (Hiebert et al., 2017).

Findings from a recent empirical study support this theory (Ginestet et al., 2021). Skilled adult readers' visual processing of multisyllabic, morphologically complex and multisyllabic, orthographically complex pseudowords was measured with eye movement measures (fixation durations while reading sentences), as well as an orthographic learning paradigm in which participants read each pseudoword four times within a text. Results showed morpho-orthographic structure supported faster processing of complex, multisyllabic words. In addition, frequent encounters with morphologically complex pseudowords yielded stronger learning than morphologically simple words. Thus, processing words via their constituent morpho-orthographic units may contribute to more efficient processing and learning than those that must be processed via grapheme-phoneme mappings or non-morphological syllables.

Importantly, morphological processing may not support automatic word reading until late in adolescence. For example, lexical decision findings indicate that adults and high school students (ages 16-17) are slower to reject pseudowords that contain a real stem and suffix (e.g., *earist*) than control pseudowords with no morphological structure (e.g., *earlit*). However, elementary school students (ages 7-9) and younger middle school students (ages 12-13), as well as adults and high school students, displayed lower accuracy for the pseudo-suffixed words than for the control words (Dawson et al., 2018). Therefore, although morphological structure impacted processing efficiency and accuracy for high school students and adults, it only influenced accuracy for elementary and younger middle school students.

Similar findings can be found in studies using oral word reading tasks. For example, Deacon et al (2011) asked students in Grades 4, 6, and 8 to read derived words with low surface frequencies. Grade 4 and 6 students were more accurate in reading words that contained high-frequency stems than those that contained low-frequency stems. However, students in Grade 8 only exhibited faster *response times* as a result of morphological structure – there was no effect on accuracy. Thus, morphological structure contributes to automaticity in later grades. In addition, McCutchen et al., (2009) examined priming effects based on morphological structure in Grades 5 and 8. While shared morphological structure (between the target and prime) led to more priming than shared orthographic or semantic structure, Grade 8 students showed a significantly larger effect of priming than younger students. Finally, Carlisle and Stone (2005) showed that high school students recognize phonologically transparent and opaque derived words faster than middle school students, and middle school students are slower to read opaque words than transparent words.

Together, these findings suggest morphological structure impacts word reading accuracy in younger students, but its impact on efficiency may continue to develop through middle and high school. This notion is supported by evidence from the cognitive neuroscience literature indicating that ventral areas of the brain, which are associated with morpho-orthographic segmentation and word reading in the direct, $O \rightarrow S$ pathway (Lewis et al., 2011) continue to develop from ages 7 to 13 (Ben-Shachar et al., 2011). Until the areas associated with this more direct pathway are developed, students may rely on the indirect (and less efficient) $O \rightarrow P \rightarrow S$ pathway to read words (Rastle, 2019).

Taken together, these findings indicate that morphological structure may support word *knowledge* throughout elementary school but may not impact *automaticity* until middle or high school. As students enter middle school, they not only encounter increasing numbers of morphologically complex words (Hiebert et al., 2018) but also practice reading these words in a variety of contexts (Lane et al., 2019). These contexts may include reading morphologically complex words in different kinds of texts and sentences, as well as seeing different combinations of morphemes within morphologically complex words.

Such contextual variation is key to supporting the acquisition of statistical regularities in language (Adelman et al., 2006; Gómez, 2002). Consequently, frequent and varied exposure to morphologically complex words may foster the acquisition of stable (and connected) representations of morpho-orthographic, morpho-semantic, and morpho-phonological regularities via morpho-orthographic chunking (Nagy et al., 2014; Rastle & Davis, 2008). Until adolescence, younger students may continue to develop explicit morphological abilities (i.e., morphological awareness skills) and simultaneously acquire morphological regularities (Levesque et al., 2021). However, their representations of these regularities may not be stable enough to support automatic word reading through rapid morphological decomposition (Rastle, 2019). For example, younger students may have the ability to decompose the stems in morphologically complex words, supporting word reading accuracy, but may not also take advantage of affixes to fully chunk the word (Dawson et al., 2018).

Therefore, middle school may be the crux in the transition from the *effortful use of knowledge* of morphological structure to support word reading accuracy to the *automatic activation* of morphological structure to support automatic word reading. As such, morphological processing may support reading fluency and comprehension in middle school students (Nagy et al., 2014; Perfetti & Statfura, 2014; Rastle, 2019). Morphological processing, underpinned by morpho-orthographic chunking, may free attentional resources needed to decode complex, multisyllabic words and similarly free working memory to read fluently and devote limited cognitive resources to language processes (e.g., comprehension; Logan, 1997; Perfetti, 1985). Importantly, findings from a longitudinal study of late elementary to middle school support this hypothesis (Nunes et al., 2012). Students' use of morpho-orthographic units at ages 8-9 contributed a larger amount of variance to word reading efficiency, reading fluency (as measured by oral reading rate of connected text), and reading comprehension at ages 12-13 than their use of grapho-phonemic units. This is consistent with findings indicating students begin to rely more on morphological ability than phonological ability to read as they enter the later elementary school years (Carlisle, 2000; Singson et al., 2000). Thus, morphological processing may be a critical contributor to reading fluency of middle school students, which, in turn, supports their comprehension. Conversely, it may be that relying too much on morphological information signals weak lexical representations that hinder reading comprehension in older students (Gilbert et al., 2014).

Rationale and Purpose

We know little about the contribution of morphological processing to decoding, reading fluency, and reading comprehension in middle school students. There is some evidence that morphological processing makes a unique contribution to reading comprehension relative to other types of morphological ability (Goodwin et al., 2017, 2020). However, findings are mixed as to whether morphological processing helps or hinders comprehension in middle school students in general. More importantly, the extent to which morphological processing is automatic could influence its unique contribution to reading fluency and comprehension, as more effortful use of morphological structure in word reading may tap cognitive resources needed to read fluently and comprehend text.

Critical insight might be had by deploying the masking paradigm of Roembke et al. (2019, 2021) with morphologically complex or simple words. Zimmermann et al. (2024) present a first step in this direction. Children completed four tasks with masked stimuli (to capture automaticity) and unmasked (to capture knowledge). Half the items in these experimental tasks were morphologically complex, and half were not. Four tasks were used. As in Roembke et al. (2019), children completed a word-to-picture matching task and a task where they had to verify if the auditorily presented word matched the written form. In addition, they added a read aloud task, and a syllable counting task. All four tasks showed a strong masking decrement. However, this was reduced for morphologically complex words in the read aloud task (with some evidence for a similar pattern in the picture matching task). This supports the idea that morphological structure can provide “chunks” that allow children to read words automatically (for some purposes).

This study did not attempt to relate performance to individual differences in ability. In fact, the critical evidence for the independence of automaticity from reading knowledge in Roembke’s prior work came from a double dissociation in which masked performance predicted fluency, while unmasked predicted decoding. Such effects could establish whether morphological structure contributes to automaticity more broadly, and whether any benefits from morphological structure are functionally useful for real reading skills. We thus returned to that dataset by relating performance in each condition (e.g., morphologically complex + masked) to standardized assessment outcomes (decoding, fluency, comprehension) in commonality analyses. This data was then used to address the following research questions:

1. What is the unique contribution of masked performance (automaticity) to the decoding, oral reading fluency, and reading comprehension abilities of middle school students? This was intended as a replication of Roembke et al (2019, 2021), where masked performance should largely predict fluency and unmasked performance should largely predict decoding. We also hypothesized that masked performance would predict comprehension, a replication of findings with multisyllabic words in Roembke et al. (2021).
2. What is the unique contribution of accuracy in reading morphologically complex words (morphological processing) to the decoding, oral reading fluency, and reading comprehension abilities of middle school students? If morphological chunking is critical to word recognition skills, performance with complex words should be more predictive than simple words. However, if simple words are more predictive, it would suggest that nonmorphological structures are more difficult to acquire and apply, thus making them a critical bottleneck to skilled reading.
3. Does accuracy in masked performance (automaticity) in reading morphologically complex words (morphological processing) account

for unique variance (relative to morphologically simple words) in the decoding, oral reading fluency, and reading comprehension abilities of middle school students? Here if morphological chunking is critical for automaticity, we expected performance on complex words in masked presentation to be uniquely predictive of fluency and comprehension. On the other hand, if masked performance with simple words is more predictive, reliance on morphological structure may reflect weak lexical representations that create difficulty in achieving automaticity.

Methods

Data collection procedures were approved by the Institutional Review Board at the University of Iowa. At the beginning of the first session, parents/guardians provided consent for participation, and children provided assent.

Participants and Setting

Data were collected from November 2021 to February 2022. Participants were 80 English-speaking students enrolled in Grades 7 or 8 in the United States and between the ages of 12 and 14. Demographic information for the sample is shown in Table 1. Study sessions were conducted remotely to minimize risk posed by the ongoing COVID-19 pandemic. Participants were excluded based on parent/guardian report if they had an intellectual disability, were an English learner, or had an uncorrected vision or hearing impairment.

Standardized Assessments

All standardized assessments were administered remotely over Zoom and audio recorded. Stimuli were presented to participants on presentation slides via the screen sharing function. Participants were required to use a computer or tablet for the assessments—cell phones were not used due to small screen sizes that may have hindered their ability to see the assessment items.

Reading Assessments

Four standardized reading assessments were administered to measure participants' decoding, oral reading fluency, and reading comprehension abilities. Three of these assessments were subtests of the Woodcock Reading Mastery Test, Third Edition (WMRT-III; Woodcock, 2011). One subtest of the Gates-MacGinitie Reading Tests, Fourth Edition (GMRT-4; MacGinitie et al., 2000) was administered. Standard scores were calculated for all WRMT-III subtests. Standard scores are not available for the GRMT-4; however, the test developer provides percentiles, which were converted to standard scores. Reliability estimates beţlow are from the test developers.

WMRT-III. The WRMT-III Basic Skills cluster was used to measure decoding and comprised two untimed subtests: Word Identification and Word Attack (both Form A). Students read aloud 46 high-frequency words (Word Identification) or 26 nonsense words (Word Attack) of increasing difficulty. Split-half reliability for Word Identification is .89 for Grades 7 and 8, and for Word Attack it is .85 and .80 for Grade 7 and 8. Split-half reliability for the Basic Skills cluster is .92 and .91 for Grade 7 and 8, respectively.

The WRMT-III Oral Reading Fluency subtest (Form A) was also administered. Participants read aloud two passages, and the examiner marked any errors (i.e., substitutions, additions, omissions, mispronunciations, reversals, repetitions) to determine the number of words read correctly per 10 s. Split-half reliability is .95 for Grades 7 and 8.

GMRT-4. The GMRT-4, Comprehension subtest (Form S), is a timed assessment of reading comprehension. It is typically administered in groups but was administered individually. Students had 35 min to read 11 narrative and expository passages and answer 3 to 6 multiple-choice questions, for a total of 48 questions. Split-half reliability for Level 7/9 is .91.

Oral Language Assessments

In addition to the reading assessments, two oral language assessments were administered: the Word Derivations subtest of the Test of Adolescent and Adult Language, Fourth Edition (TOAL-4; Hammill et al., 2007) and the Picture Vocabulary subtest of the Woodcock-Johnson Tests of Cognitive Abilities, Fourth Edition (WJ-IV; Schrank et al., 2014). These assessments were used as covariates to account for students’ oral language abilities, which account for a large portion of the variance in reading outcomes of middle school students (e.g., Eason et al., 2013; Nation & Snowling, 2004). Standard scores were calculated for both oral language assessments.

TOAL-4. The TOAL-4 Word Derivations subtest is an untimed, individually-administered assessment of derivational morpheme knowledge. The examiner read aloud one key word and one complete sentence and asked the participant to complete a second related sentence using a derivation of the key word. The subtest consists of 51 items. Cronbach's alpha for ages 12 to 14 ranges from .91 to .94. Test-retest reliability is .91.

WJ-IV. The WJ-IV Picture Vocabulary subtest is an individually-administered assessment of expressive vocabulary knowledge. Students viewed pictures of objects that decreased in familiarity and were asked to name each object. Split-half reliability ranges from .78 to .87 for ages 12 to 14.

Assessment Procedures

All assessments were administered in a single session via Zoom by the first author. Participants first completed the Comprehension subtest of the GMRT-4. Then the remainder of the standardized assessment battery was administered in the following order: WRMT-III Word Identification, WRMT-III Word Attack, WRMT-III Oral Reading Fluency, WJ-IV Picture Vocabulary, and TOAL-4 Word Derivations.

Experimental Measure

All experimental tasks were completed by students in a second session via an online research platform that was developed and delivered by Foundations in Learning (FIL), Inc. This platform, used in the two previous studies of automaticity and reading (Roembke et al., 2019, 2021), is derived from WordFlight, a commercially available literacy system from FIL. It was designed foster participant engagement and consists of colorful graphics and a game-like structure. Existing tasks were customized for this study by modifying word lists and other properties (e.g., feedback delivery). While participants completed these tasks on the WordFlight application, an experimenter monitored on a simultaneous Zoom session in screen sharing mode to ensure participants understood and stayed engaged in the tasks.

After logging in participants viewed a colorful selection screen that displayed a map with different ‘locations.’ Participants clicked on a location that led them to complete a set of 20 trials in one of the four experimental tasks, with either masked or unmasked stimuli (all the same within a block). They then could choose another location to complete another block of 20 trials. This was intended to minimize boredom and fatigue as they never did too many trials of the same type.

Participants completed four visual word recognition tasks: *Find the Picture, Verify the Word, Count the Number of Syllables,* and *Say the Word.* To facilitate readability, these tasks are referred to as the following: *Find the Picture* = *Picture*; *Count the Number of Syllables* = *Syllables*; *Say the Word* = *Say*; and *Verify the Word* = *Verify*. These tasks were chosen to diversify the task response modality (oral vs. silent) and the pathways (*O→S*; *O→P→S*) through which morphological structure may contribute to reading (see Table 2 for a summary of the tasks). All tasks were implemented in a masked and an unmasked version. Across the tasks, two types of items were used: morphologically complex words (e.g., *eagerness*) and morphologically simple words (e.g., *embarrass*). These item types are referred to as *complex* and *simple* words, respectively, to facilitate readability.

Overall masked performance (automaticity) and overall unmasked performance (knowledge) were used to answer RQ1. To address RQ2, we calculated overall accuracy for complex (morphological processing) and simple (nonmorphological processing) words across masked and unmasked tasks. These factors were crossed to create four additional independent variables that were used to answer RQ3: masked performance with complex words (masked/complex), masked performance with simple words (masked/simple), unmasked performance with complex words (unmasked/complex), and unmasked performance with simple words (unmasked/simple).

Design

In all tasks, a written target word was presented, and participants produced a response. In unmasked task versions, the target word remained on the screen, and participants had unlimited time to respond. In masked task versions, the target word was presented for 90 ms and then covered with a series of 11 hashtags, ensuring that the number of hashtags exceeded the length of the longest items. Participants completed 80 experimental trials of *Syllables, Picture*, *Say*, and *Verify* each, for a total of 320 trials. For each task, 40 of the items were complex words, and 40 were simple words. Similarly, 40 of the trials were masked, and 40 were unmasked. A separate word list for each task was used (i.e., each list contained 80 words), and the order in which the words were presented was randomized within each 20-trial block. Each complex word was matched with a simple word on length, syllables, log HAL frequency, and orthographic neighborhood size. The matched pairs were assigned to tasks together, allowing these factors to be roughly counterbalanced within tasks and across masked and unmasked versions of each task.

Experimental Tasks

Picture. In the *Picture* task, a written target word was presented, along with four potential pictures to represent it. Participants clicked on the picture that matched the target. Foils were words that were phonologically or orthographically similar to the target (e.g., *cardinal* as a foil for *carnival*). Semantic competitors (e.g., *festival* as a foil for *carnival*) were not used to avoid confusion among the pictures. The order of the pictures on the screen was randomized on each trial for each participant. Each picture was used in one trial and not reused in other trials as foils.

Verify. In the *Verify* task, one spoken and one written target were presented simultaneously. Participants clicked on a green button to indicate a match or a red button to indicate a mismatch In half of the trials, the stimuli matched. When they did not match, the auditory stimulus was a close orthographic or phonological competitor. Some had similar onsets (e.g., *freezer* and *freedom*), and some had similar offsets (e.g., *freezer* and *blazer*). As in *Picture*, each word appeared once and was not reused across trials. Words were counterbalanced across participants, appearing in the match condition for some and the mismatch condition for others.

Syllables. In the *Syllables* task, a written target word was presented. Participants clicked on the correct number of syllables (1, 2, 3, or 4). This task was not used in the prior studies that implemented the backward masking paradigm.

Say. In the *Say* task, a written target word was presented, and participants read the word aloud. Recording was initiated at the onset of the word and lasted until the participant clicked a button to indicate a completed response. Recordings were scored offline for accuracy.

For the unmasked version of *Say*, the first trial in the first block for each participant was removed due to a technical error (i.e., 80 unmasked trials [out of 3,200 total trials] were excluded from the analyses). In addition, 157 had recording problems due to participant error, microphone issues, or Internet connectivity. In such cases, we returned to the corresponding session recording to find the participant's response, resolving most issues (99 of 157 trials). However, 58 trials for which a response could not be found or clearly heard were excluded from analyses. In total, 138 trials of the unmasked version of the task (approximately 4.3% of trials) were excluded.

Items

Items were real English words likely to be known by middle school students (see online supplemental materials for complete list). All items had an age of acquisition of 11.0 years of age or less to ensure accessibility for students in grades 7 and 8 (ages 12 to 14). Like the multisyllabic words used by Roembke et al. (2021), words contained 2 or 3 syllables. All words had a length of 5 to 10 letters. Words recently borrowed from other languages were not included (e.g., *fiesta* from Spanish).

Items fell into one of two between-item conditions: simple and complex words. Morphological status was determined using the WebCELEX database (Max Planck Institute for Psycholinguistics, 2001). Complex words were bimorphemic words composed of one stem and one derivational suffix (e.g., eager + -ness → *eagerness*). Simple words were monomorphemic and could not be morphologically decomposed (e.g., *embarrass*). All complex words contained unique stems, but some suffixes were repeated.

Items were balanced on factors known to impact visual word recognition. Items were balanced on length (the number of letters) and number of syllables. which both predict pronunciation and lexical decision times (Yap & Balota, 2009). Words were also balanced on frequency, indexed with the log-transformed Hyperspace to Analogue Language (HAL) norms (Lund & Burgess, 1996) and orthographic neighborhood size (Coltheart et al., 1977) both of which also account for the large amounts of variance in visual word recognition (Brysbaert et al., 2016, Yap & Balota, 2009). Finally, suffixes were balanced across tasks to the greatest extent possible.

Within each task, items in the complex and simple conditions and in the masked and unmasked task versions were equated on these factors. We also balanced items across each task. Table 3 contains the means for each factor across conditions and tasks.

Procedural Fidelity and Inter-Rater Reliability

Experimental task supervisors completed a 2-hr training session with the first author and were required to achieve 100% fidelity in a session before independently conducting subsequent sessions. Administration of the assessments and experimental tasks were audio recorded for reliability scoring and procedural fidelity monitoring. The first author periodically listened to experimental task sessions for each supervisor and provided feedback.

Inter-rather reliability and procedural fidelity each were assessed by an independent observer for 20% of participants, randomly selected on a biweekly basis throughout data collection. Procedural fidelity was measured with separate checklists for the experimental sessions and each assessment. Overall, procedural fidelity was high (range = 98% to 100%). Inter-rater reliability was assessed for all measures requiring a rater judgment (WRMT-III Word Identification, Word Attack, and Oral Reading Fluency, TOAL-4 Word Derivations, WJ-IV Picture Vocabulary, and *Say*). For all measures, each word or pseudoword was counted as a response, and point-by-point agreement was measured. Inter-rater reliability for all measures was high (range = 95% to 99.8%).

Analyses

A series of commonality analyses was conducted to answer the research questions. This approach predicted an outcome (e.g., fluency) from various factors, decomposing the R^2 of each into the proportion of variance uniquely associated with each independent variable or shared among independent variables and covariates. For each task (*Picture*, *Say*, *Syllables*, and *Verify*), a separate commonality analysis was conducted for each reading outcome (decoding, oral reading fluency, and reading comprehension), following Roembke et al. (2019). Commonality analyses were conducted using the *yhat* package (Nimon et al., 2021) in R (Version 4.1.2l R Core Team, 2021). To determine the variance shared by variables of interest and language, as well as variance shared among other combinations of variables (i.e., Shared—Other on Figures 2-4), corresponding R^2 values from the commonality results were summed. Significance of unique effects were determined using hierarchical regressions (see the online supplemental materials for results of the hierarchical regressions). Prior to conducting these analyses, all independent variables and covariates were mean centered.

RQ1: Unique Contribution of Masked Performance

To determine the unique role of masked performance (automaticity) in reading outcomes. a series of commonality analyses were conducted that examined the unique contribution of masked performance and unmasked performance (averaged across simple and complex words) to each outcome, as well as the variance shared by these variables with oral language.

RQ2: Unique Contribution of Accuracy with Morphologically Complex Words

To determine the unique role morphological processing, a series of commonality analyses were conducted that examined the unique contribution of performance with complex words and simple words (averaged across unmasked and masked tasks) to each reading outcome, as well as the variance shared between these variables with oral language.

RQ3: Unique Contribution of Masked Performance with Morphologically Complex Words

To determine whether masked performance (automaticity) with complex words (morphological processing) accounted for unique variance in reading outcomes, commonality analyses partitioned the unique variance accounted for by masked/complex, masked/simple, unmasked/complex, and unmasked/simple, as well as the variance shared by each of these variables with oral language.

Results

Standardized Assessments

Means and standard deviations of performance on the standardized assessments are displayed in Table 4.

Experimental Measures

Figure 1 shows accuracy as a function of masking. Results from a series of mixed ANOVAs indicated a consistent performance decrement for masking across tasks, replicating the effect for masking from Roembke et al. (2019, 2021). These results are described more comprehensively in a prior study with the same sample (Zimmermann et al., 2024). We summarize them here to contextualize the results of the present study.

The main effect of morphological status was significant on two tasks: *Picture* and *Say.* Accuracy was significantly higher for complex words than simple words in *Say*, and the opposite was true for *Picture*. There was a significant interaction between masking and morphological status on the same two tasks. Results from pairwise comparisons indicated that students were significantly more accurate in masked/complex than masked/simple on *Say* and unmasked/simple than unmasked/complex on *Picture*. On *Picture*, the masking decrement for complex words was smaller than for simple words; however, this result was not significant.

Depiction of Commonality Analysis Results

Results of the commonality analyses are displayed in Figures 2-4. Figures are organized as stacked bar charts where the total height of the bar is the total variance accounted for by the model, and the sections indicate the amount of unique and shared variance accounted for by oral language and accuracy in various experimental conditions (e.g., masked/unmasked, simple/complex). All results are organized by reading outcome (decoding, fluency, and comprehension). Table 5 shows the proportion of unique variance accounted for by the variables of interest in all research questions, as well as the total variance subsumed by each model. Overall models were highly significant, accounting for 40-60% of the variance in decoding (depending on the task), 25-40% of the variance in fluency, and about 40% of the variance in comprehension. Language accounted for substantial variance in all outcomes – about (10-20% unique variance), with additional variance shared with the other predictors.

RQ1: Unique Contribution of Masked Performance

The first research question asked whether masked performance (a proxy for automaticity, averaged over the morphologically simple and complex words) contributed unique variance to reading outcomes. Results are shown in Figure 2 and Table 5.

Unique Contribution of Masked Performance to Decoding

Both unmasked and masked performance contributed unique variance to decoding, replicating Roembke et al. (2021). Unmasked performance was only uniquely significant for *Say,* where it contributed 8.5% of the unique variance (= .085; $p < .001$). Masked performance accounted for unique variance on two tasks: on *Picture* it uniquely accounted for 9% of the variance (= .09; $p < .001$), and on *Syllables* it uniquely accounted for 4% of the variance (= .042; $p = .017$).

Unique Contribution of Masked Performance to Oral Reading Fluency

Unmasked performance did not contribute any unique variance to oral reading fluency for all of the experimental tasks. This replicates prior work that applied the backward masking paradigm with middle school students

(Roembke et al., 2019, 2021). Instead, masked performance accounted for significant unique variance on three tasks: *Picture*, *Say*, and *Syllables*. On *Picture*, it uniquely accounted for almost 17% of the variance (= .169; $p <$ .001); on *Say* it uniquely accounted for 4% of the variance (= .041; $p =$ .033); and on *Syllables* it uniquely accounted for 5% of the variance (= .051; $p = .025$).

Unique Contribution of Masked Performance to Reading Comprehension

Similar to the oral reading fluency results, unmasked performance did not account for any unique variance. Instead, masked performance accounted for approximately 5% of the unique variance on two tasks: *Picture* (= .051; $p = .007$) and *Syllables* (= .053; $p = .007$). This replicates the findings of Roembke et al., 2021, who found that masked performance with multisyllabic words contributed unique variance to comprehension.

RQ2: Unique Contribution of Morphological Processing

We next asked whether accuracy in reading complex words (averaged over masked and unmasked task versions) contributed unique variance to reading outcomes. Results are shown in Figure 3 and Table 5.

Unique Contribution of Morphological Processing to Decoding

Accuracy in reading simple words contributed unique variance to decoding on two tasks: on *Picture*, it accounted for 3% of the variance (= .033; $p = .033$), and on *Say* it accounted for 6% of the variance (= .062; $p =$ .001). Accuracy in reading complex words did not contribute unique variance to decoding on any of the experimental tasks. However, on *Picture*, 2% (= .02) of the total variance was shared between complex word performance and oral language.

Unique Contribution of Morphological Processing to Oral Reading Fluency

Similar to the results for decoding, only accuracy in reading simple words (nonmorphological processing) contributed unique variance to fluency. It accounted for 7% of the unique variance on *Picture* (= .07; p = .007) and approximately 4% of the variance on *Say* (= .036; p = .044).

Unique Contribution of Morphological Processing to Reading Comprehension

On the *Syllables* task, accuracy in reading complex words contributed approximately 4.5% of the unique variance to reading comprehension outcomes (= .045; p = .011). In addition, on *Picture*, variance shared between complex word performance and language accounted for approximately 3% of the variance (= .034). Accuracy in reading simple words did not contribute unique variance to reading comprehension on any of the tasks.

RQ3: Unique Contribution of Masked Performance with Morphologically Complex Words

The primary research question was whether automatic morphological processing (masked/complex) accounted for unique variance in reading outcomes. Results are shown in Figure 4 and Table 5.

Unique Contribution of Automatic Morphological Processing to Decoding

The commonality analyses found that masked/simple, unmasked/complex, and unmasked/simple each contributed significant unique variance to decoding. Masked/simple on *Say* accounted for approximately 5% of the variance (*Say*: = .0508; p = .002). Unmasked/complex contributed 4% of the variance on *Say*, and unmasked/simple contributed over 2% of the variance (unmasked/complex: = .0422; p = .0037; unmasked/simple: = .0235; p = .025). Notably, there was no significant unique contribution of masked/complex. However, on *Pictur*e, masking, morphology, and language together accounted for 2% of the variance (= .022).

Unique Contribution of Automatic Morphological Processing to Oral Reading Fluency

Masked/complex on *Syllables* significantly accounted for approximately 5% of the unique variance in oral reading fluency (= .0463; p = .033). Moreover, on *Picture*, variance shared among masking, morphology, and language totaled about 1% = .012). Masked/simple also contributed significant unique variance to oral reading fluency Masked/simple contributed 4% of the variance on *Say* (= .0411; p = .031) and 7% of the variance on *Picture* (= .07; p = .006). In sum, results for oral reading fluency differed from those of decoding in that only masked performance contributed significant unique variance, with masked/simple most consistently contributing unique variance.

Unique Contribution of Automatic Morphological Processing to Reading Comprehension

Masked/complex uniquely accounted for approximately 6% of the variance on *Syllables* (= .0608; p = .004). No other variables contributed significant unique variance to comprehension.

Discussion

This study asked how middle school students develop automaticity in service of reading outcomes and, specifically, whether and how they *apply* morphological structure to support their decoding, oral reading fluency, and reading comprehension. We start by discussing limitations before turning to the key findings.

Limitations

There were several limitations to the study. First, technical errors led to a small amount of data-loss for *Say* that may have reduced reliability. Second, the standardized assessments were administered remotely, rather than in-person (as intended by the developers); this may have impacted student performance on the assessments. In particular, because the GMRT-4 was administered in a 1:1 remote format, rather than an in-person group format, students may have been more motivated to perform, engage with the passages, and check their work. However, our research questions concerned relative—not absolute—scores. Thus, differences in performance of the sample as a whole would not have likely impacted results.

Decoding

Findings from this study replicate previous findings that decoding is influenced by the convergence of *knowledge* of orthographic, phonological, and semantic regularities (Roembke et al., 2019, 2021). The present study extends those findings in two ways. First, this was only seen in the *Say* task. This strength of this task makes sense as this task most closely indexes the *O→P* mappings needed for decoding. It was unclear why this did not appear in the other tasks.

Second and more importantly, we show that nonmorphological structure, but not morphological structure, contributes unique variance to decoding (RQ2). However, when we divorced the knowledge of nonmorphological and morphological structure from the automaticity in applying this structure (RQ3), the findings for decoding differed: knowledge of *morphological* structure contributed unique variance to decoding. This may be because students have learned chunks of morpho-orthographic regularities that can be reliably mapped to phonology via the *O→P* pathway or directly to semantics via the *O→S* pathway (Levesque et al., 2021).

Finally, this study replicates previous findings that *automaticity* in reading multisyllabic words also contributes unique variance to decoding (Roembke et al., 2021). Results suggested that students may have sufficient *nonmorphological* regularities that are applied automatically to support decoding. In contrast, findings for morphologically complex words indicated that middle school students have acquired morpho-semantic and morpho-orthographic regularities, but these regularities are not yet stable enough for students to rapidly activate and apply them in a way that substantially impacts word reading over and above regularities afforded by simple words. It may be that middle school students can apply *knowledge* of morphological structure to support decoding but cannot *automatically* activate morphological regularities in the *O*→*S* pathway to make a unique contribution to decoding. However, it may also be possible that automatic activation of morphological structure is not required to perform well on the WJ-III decoding measures due to the relatively few morphologically complex items and untimed format.

Oral Reading Fluency

As in Roembke et al. (2019, 2021), only automaticity contributed significant unique variance to oral reading fluency, providing additional support for the theoretical contribution of automaticity to oral reading fluency (e.g., LaBerge & Samuels, 1974; Perfetti, 1985). In addition, results again revealed the importance of simple words. In fact, automatically activating semantic information from simple words (in the *Picture* task) contributed the largest amount of unique variance. Thus, processing words in the *O*→*S* pathway appears critical to fluent reading in middle school students, highlighting the role of this pathway in automatic word reading (Harm & Seidenberg, 2004). Moreover, if students could automatically apply *phonological* information in simple words (*Say*), their fluency also benefitted, underscoring the role of automatic activation in the *O*→*P* pathway. Overall, these findings indicate that middle school students have acquired nonmorphological regularities that are sufficiently stable to be automatically activated in both pathways in support of reading fluency.

The primary question, though, was whether automatically processing morphological structure makes students more fluent readers of connected text. Overall, the effects of automaticity for complex words were less consistent and smaller than for simple words. However, its sole significant unique contribution (in the *Syllables* task) revealed a developing role of morpho-orthographic decomposition in middle school students. Critically, *Syllables* was the task that most closely captured morph-orthographic segmentation and required the most strategic use of morphological structure to produce a correct response. Thus, the ability to automatically process morpho-orthographic chunks and apply these regularities contributes to the oral reading fluency of middle school students.

Results from *Picture* revealed a similar story for the automatic use of morpho-semantic information: the strength and activation of morpho-semantic regularities is not sufficient to support automaticity in the $O \rightarrow S$ pathway (i.e., the difference in the masking decrement for complex and simple words was not significant; Zimmermann et al., 2024) and influence oral reading fluency in middle school students in the present study. However, the relatively small number of morphologically complex words on the WJ-III ORF passages may have precluded morph/mask from contributing unique variance to oral reading fluency. Another potential explanation is that because simple words do not afford morpho-orthographic chunking, (and thus require activation of more fine-grained orthographic and phonological regularities), they may be more difficult to acquire, thus creating a bottleneck that must be opened to achieve fluent reading.

In sum, these findings reveal that middle school students are engaging in some rudimentary chunking of morpho-orthographic units to support fluency. However, their representations of morpho-orthographic and morpho-semantic units are not stable enough to be applied to other information (phonological, semantic) to support fluent reading in relatively implicit ways or via the direct $O \rightarrow S$ pathway.

Reading Comprehension

Findings for reading comprehension showed a similar picture for automaticity but a larger role of morphological processing than for decoding and oral reading fluency. Automaticity, but not knowledge, contributed unique variance to reading comprehension, replicating previous findings from Roembke et al. (2021). However, only complex words uniquely contributed significant variance to reading comprehension, and, like fluency, this was only seen on *Syllables.* This may indicate that automatically processing morpho-orthographic chunks is a scaffold to the development of skilled reading via the $O \rightarrow P \rightarrow S$ pathway, aiding in the understanding of multisyllabic words critical to reading comprehension (Rastle & Davis, 2008). In addition, given the relatively explicit nature of the knowledge required to produce a correct response in *Syllables,* students may be applying morpho-orthographic information in strategic ways during reading. This supports previous findings that morphological processing contributes unique variance to comprehension, even when accounting for general morphological knowledge (Goodwin et al., 2020). Thus, middle school students may still be developing the ability to apply morphological processing in more implicit ways and via the direct $O \rightarrow S$ pathway to improve reading.

Implications

This study has several important initial implications for our understanding of the role of morphological processing in middle school reading. Although middle school students exhibit some sensitivity to morphological structure (Zimmermann et al., 2024), they have not yet developed sufficiently stable representations of these structures to use them in relatively implicit ways or via the $O \rightarrow S$ pathway to improve their reading. Instead, the role of morphological processing may still be developing in middle school students—they can automatically activate orthographic and phonological information in morphemes and engage in strategic chunking of morpho-orthographic units to support fluent reading and comprehension. However, their use of morphological structure remains relatively explicit and possibly effortful.

Middle school students were able to automatically apply one type of morphological processing to benefit oral reading fluency and comprehension: rudimentary morpho-orthographic chunking as seen in

Syllables. This speaks to the potential development of morpho-orthographic decomposition in this population. If morpho-orthographic decomposition continues to develop with increased reading experience, there may be a larger effect of morphological processing on students' reading abilities later in the secondary school years. Research is needed to examine the role of morphological processing in older secondary school students and determine whether the role of morphological processing continues to develop with increased reading experience from middle to high school.

Findings from the present study do not support a substantial *unique* role of morphological processing in the reading abilities of middle school students. However, frequent and varied practice may allow students to strengthen their representations of morphological structures and benefit their reading abilities.

Disclosure of Interest

The authors have no competing interests to declare.

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Table 1. *Demographics of the Sample*

Characteristics		Frequency/ Percentage
Age	Age 12	30 (37.5%)
	Age 13	39 (48.75%)
	Age 14	11 (13.75%)
Grade Level	Grade 7	53 (66.25%)
	Grade 8	27 (33.75%)
Gender	Female	42 (52.5%)
	Male	38 (47.5%)
Ethnicity	Asian	2 (2.5%)
	Caucasian	74 (92.5%)
	Hispanic	2 (2.5%)
	Multiple Ethnicities	2 (2.5%)

Table 2. *Description of Experimental Tasks by Knowledge and Pathway*

Task	Response	Pathway(s) Targeted
Syllables	Silent; segment the word via orthographic and/or phonological units	O→P→ S
Picture	Silent; identify a picture that best represents the word's meaning	O→S
Say	Oral; pronounce the word	O→P→S O→S
Verify	Silent; indicate whether the oral and written words match	O→P→S O→S

Table 3. *Item Characteristics by Task and Morphological Status*

Characteristic	Picture		Say		Syllables		Verify	
	C	S	C	S	C	S	C	S
Length	7.25	7.25	7.35	7.35	7.40	7.38	7.3	7.28
Log Frequency	7.59	7.88	7.92	7.83	7.59	7.79	7.66	7.42
Syllables	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Orthographic Neighborhood	0.45	0.43	0.43	0.43	0.40	0.38	0.43	0.43

Note. C = morphologically complex words; S = morphologically simple words

Table 4. *Overview of Reading and Oral Language Assessments*

Outcome	*M*	*SD*
WRMT-III Basic Skills	99.63	11.72
WRMT-III Oral Reading Fluency	105.31	14.05
GMRT-4 Passage Comprehension	110.64	12.81
TOAL-4 Word Derivations	106.58	14.94
WJ-IV Picture Vocabulary	98.66	11.93

Note. WRMT-III = Woodcock Reading Mastery Tests, Third Edition; GMRT-4 = Gates-MacGinitie Reading Tests, 4th Edition; TOAL-4 = Test of Adolescent and Adult Language; 4th Edition, WJ-IV = Woodcock-Johnson Tests of Cognitive Abilities, Fourth Edition

Table 5. *Overview of Commonality Results*

			Masking			Morphology			Masking and Morphology				
Outcome	Task	Language R^2	Overall	Unmasked R^2	Masked R^2	Overall	Complex R^2	Simple R^2	Overall	Unmasked/ complex R^2	Unmasked/ simple R^2	Masked/ complex	Masked/ simple
Decoding	Picture	.4095	.5005	.0170	.0897**	.4747	.0010	.0329*	.5048	.0188	0	.0198	.0282*
	Say		.6096	.0854**	.0203	.5961	.0019	.0621**	.6467	.0429**	.0251*	.0066	.0499**
	Syllables		.4727	.0007	.0422*	.4627	.0107	.0022	.4806	.0027	.0046	.0265	.0003
	Verify		.4145	.0047	.0002	.4131	.0018	0	.4187	.0005	.0034	.0013	.0012
Fluency	Picture	.2051	.3766	.0305	.1685**	.3277	.0004	.0700**	.3697	.0235	.0014	.0250	.0700**
	Say		.3529	.0319	.0408*	.3561	.0063	.0362*	.3785	.0269	.0041	0	.0411*
	Syllables		.2723	0	.0506*	.2686	.0323	.0009	.2884	0	0	.0463*	.0002
	Verify		.2188	.0114	.0081	.2057	0	.0001	.3606	.0030	.0127	0	.0054
Comprehension	Picture	.4125	.4959	.0009	.0509**	.4964	.0104	.0232	.4965	.0025	.0001	.0078	.0245
	Say		.4419	.0002	.0198	.4411	.0004	.0092	.4588	.0038	.0022	.0001	.0243
	Syllables		.4891	.0006	.0526**	.4942	.0453*	.0023	.5149	.0007	.0002	.0605**	.0019
	Verify		.4149	.0007	.0023	.4149	.0024	.0009	.4165	0	.0002	.0036	0

Note. Picture = F*ind the Picture*; Say = *Say the Word*; Syllables = *Count the Number of Syllables*; Verify = *Verify the Word*.
p <. 05 is marked with *; *p* < .01 is marked with **; p < .001 is marked with *

Figure 1. Accuracy for experimental tasks

Note. C = morphologically complex words; S = morphologically simple words; Syllables = *Count the Number of Syllables*; Picture = *Find the Picture*; Say = *Say the Word*; Verify = *Verify the Word*. Errors bars represent the standard error of the mean.

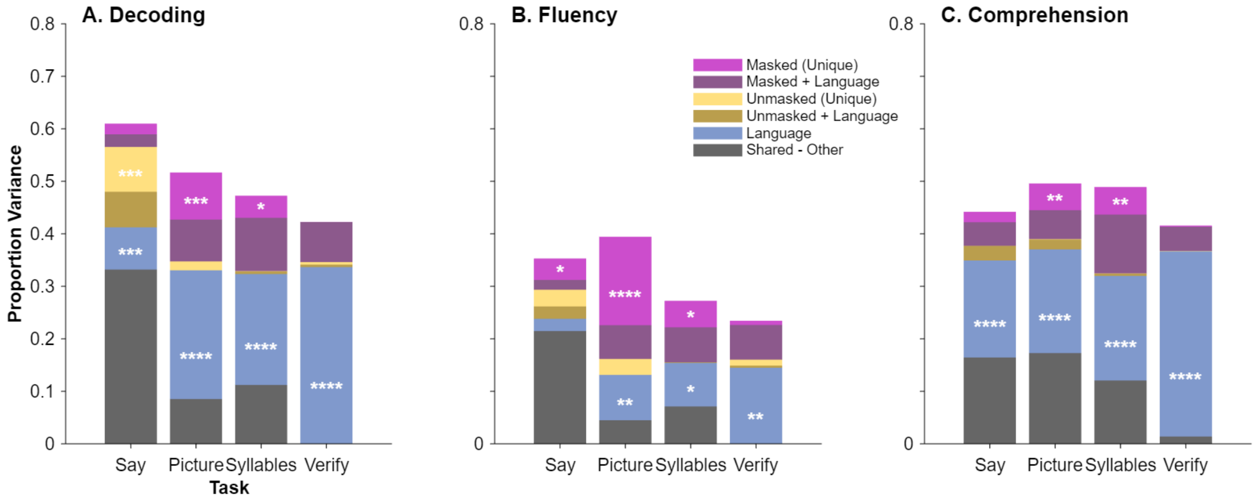

Figure 2. Unique and shared variance of masked and unmasked trials.

Note. Syllables = *Count the Number of Syllables*; Picture = *Find the Picture*; Say = *Say the Word*; Verify = *Verify the Word*. Errors bars represent the standard error of the mean.
p <.05 is marked with *. *p* <.01 is marked with **; p < .001 is marked with ***.

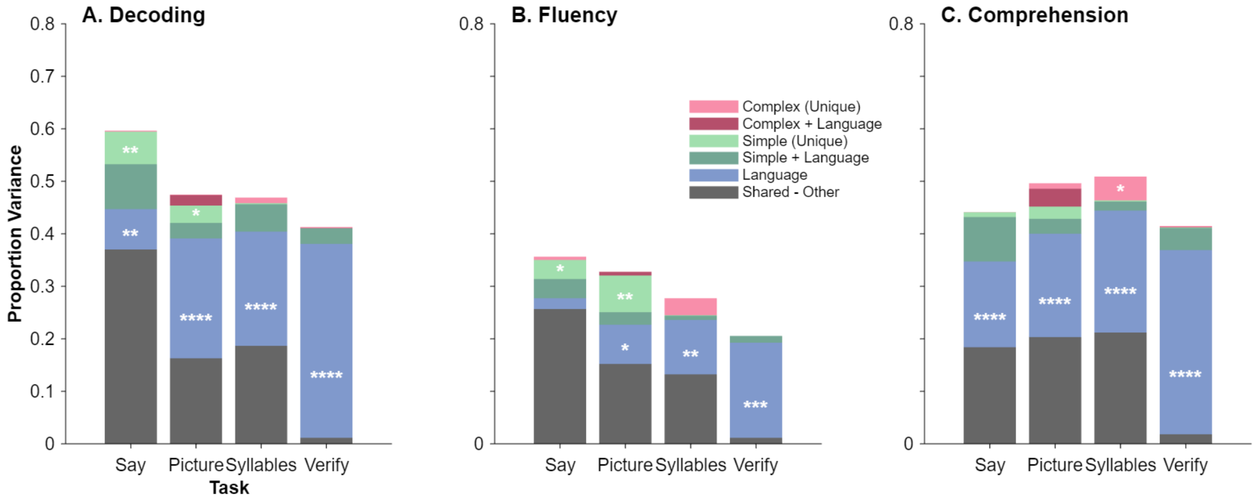

Figure 3. Unique and shared variance of morphologically complex and morphologically simple words.

Note. Syllables = *Count the Number of Syllables*; Picture = *Find the Picture*; Say = *Say the Word*; Verify = *Verify the Word*. Errors bars represent the standard error of the mean.
*p <.05 is marked with *. p <.01 is marked with *; p < .001 is marked with ***.*

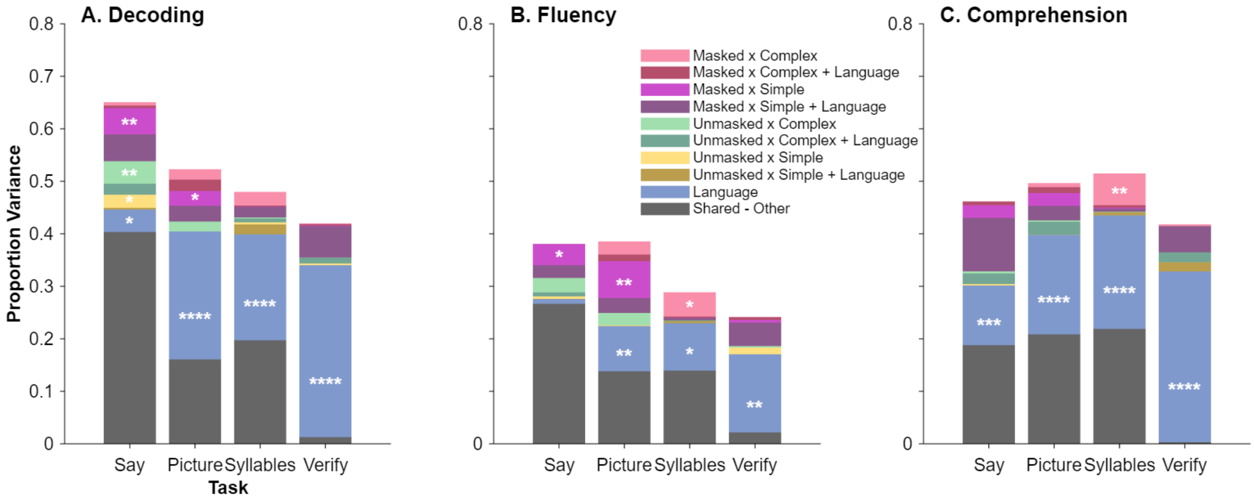

Figure 4. Unique and shared variance of masked/complex, masked/simple, unmasked/complex, and unmasked/simple.

Note. Syllables = *Count the Number of Syllables*; Picture = *Find the Picture*; Say = *Say the Word*; Verify = *Verify the Word*. Shared variance includes the variance shared by oral language, masked/complex, masked/simple, unmasked/complex, and unmasked/simple and does not include variance shared between subsets of the variables.
p <.05 is marked with *. p <.01 is marked with **; p < .001 is marked with ***