HHS Public Access
Author manuscript
*J Res Read*. Author manuscript; available in PMC 2018 February 01.

Published in final edited form as:
*J Res Read*. 2017 February ; 40(1): 91–117. doi:10.1111/1467-9817.12064.

# Exploring the Dimensionality of Morphological Knowledge for Adolescent Readers

**Amanda P. Goodwin**, **Yaacov Petscher**, **Joanne F. Carlisle**, and **Alison M. Mitchell**
Vanderbilt University's Peabody College, Florida Center for Reading Research, Florida State University, University of Michigan

## Abstract

This study examined the dimensionality of morphological knowledge. The performance of 371 seventh- and eighth-graders on seven morphological knowledge tasks was investigated using confirmatory factor analysis. Results suggested that morphological knowledge was best fit by a bifactor model with a general factor of morphological knowledge and seven specific factors, representing tasks that tap different facets of morphological knowledge. Next, structural equation modelling was used to explore links to literacy outcomes. Results indicated the general factor and the specific factor of morphological meaning processing showed significant positive associations with reading comprehension and vocabulary. Also, the specific factor of generating morphologically related words showed significant positive associations with vocabulary, while specific factors of morphological word reading and spelling processing showed small negative relationships to reading comprehension and vocabulary. Findings highlight the complexity of morphological knowledge and suggest the importance of being cognizant of the nature of morphology when designing and interpreting studies.

---

Morphemes are the smallest units of meaning in a language. In English, root words (whether bound or free) and affixes (whether prefixes or suffixes) are combined to form words that express particular meanings and serve various syntactic roles (e.g., *enforce, forceful, reinforce, forcing*). Combining root words and affixes may involve shifts in sound and spelling of the root word (e.g., *decide, decision*), making morphology a complex component of language that is integrally linked to other language components (i.e., phonology, syntax, and semantics).

Students' knowledge of morphology is significantly related to literacy achievement in the elementary years (e.g., Carlisle & Goodwin, 2013). In the middle school years, morphological knowledge becomes especially important because the textbooks and content-area instruction during this time place heavier burdens on students' academic language. Academic language is more complex and cognitively challenging than language used in everyday social interactions. It includes content-area words, many of which are morphologically complex (e.g., *hydroelectric, photosynthesis*) or which have morphological

---

Address for correspondence: Amanda P. Goodwin, PMB 230, 230 Appleton Place, Nashville, TN 37203-5721, USA. amanda.goodwin@vanderbilt.edu.

We used the Standard Frequency Index (SFI) where about half of sixth grade texts have an average SFI value of 32.

relatives (e.g., *analyse, interpret*). For example, Coxhead's Academic Word List (2000) shows that analyse is the base form used in 11 additional words (e.g., *re-analyse*) and *interpret* is used in 19 additional words (e.g., *misinterpret, interpretive*). Morphological knowledge has been found to contribute to adolescents' word reading (e.g., Carlisle & Stone, 2005; Gilbert, Goodwin, Compton, & Kearns, 2014; Goodwin, Gilbert, & Cho, 2013; Singson, Mahony, & Mann, 2000), spelling (e.g., Deacon & Bryant, 2006; Nunes, Bryant, & Bindman, 2006), and vocabulary (e.g., Carlisle & Fleming, 2003; Nagy, Berninger, & Abbott, 2006). Studies have also shown that morphological knowledge may have a direct effect on reading comprehension (McCutchen, Logan, & Biangardi-Orpe, 2009; Nagy et al., 2006; Siegel, 2008) or an effect that is mediated by relations to other variables such as vocabulary knowledge (e.g., Goodwin, 2011; Kieffer & Lesaux, 2012; Nagy et al., 2006).

Although significant associations have been found between morphology and different areas of literacy, these associations and their interpretations depend in part on how researchers are framing the construct, which relates to the different tasks and content of the measure(s) of morphological knowledge used in particular studies (e.g., Carlisle & Goodwin, 2013; Kuo & Anderson, 2006). A related (and unanswered) question is whether morphological knowledge is unidimensional or multidimensional. Unidimensionality would mean that tasks assessing different elements of morphological knowledge would draw on the same general sensitivity to morphological structures and be significantly related to each other. In contrast, multidimensionality would mean that performance on tasks assessing different morphological knowledge and processing would relate but assess different aspects of morphological knowledge.

While in theory aspects of morphological knowledge differ in important ways and relate differently to various literacy measures, we currently lack evidence to support any theoretical explanation of the dimensionality of morphological knowledge. The updated Standards for Educational and Psychological Testing (AERA, APA, & NCME, 2014) emphasise that the validity of empirical studies depends in part on the claim that measurements preserve the key characteristics of the phenomena they represent. Thus, researchers' assumptions about the nature of morphological knowledge may affect how results are interpreted to build understanding of adolescents' academic language acquisition and use. Thus, the goal of this study is to explore the dimensionality of morphological knowledge and the relation of possible dimensions to reading comprehension and vocabulary knowledge for adolescents.

## TACIT MORPHOLOGICAL PROCESSING AND STRATEGIC MORPHOLOGICAL ANALYSIS

Given different views of morphological knowledge (see Nagy, Carlisle, & Goodwin, 2014), one approach to examining dimensionality is to explore the distinction between tacit morphological processing and strategic morphological analysis. Such an approach fits within Bialystok and Ryan's (1985) framework for examining metalinguistic abilities, building on distinctions between knowledge ('knowing that is intuitive', p. 233, acquired implicitly from language learning) and analysis of knowledge ('knowing that is explicit…more analyzed forms [developed] through the increasing ability to structure and classify knowledge', p. 233). As Bialystok and Mitterer (1987) write,

> Some language uses, such as conversation, are adequately supported by unanalyzed representations of language structure, but other uses, such as reading, writing, solving metalinguistic problems, and lecturing, require a more explicit conceptualization of the units of language and their rules of combination. (p. 148)

In English, as in other languages, morphology conveys semantic, grammatical, and syntactic information (Frost, 2012). Applying the above framework, linguistic information conveyed by morphology is acquired first via tacit processing of words and sentences. Young children implicitly learn from the statistical properties of the language they are exposed to. For example, preschool children extract from experiences with -*er*, used as an agentive or instrumental suffix (*winder*) and also as a comparative form of adjectives (*tireder*), to correctly use -*er* to create novel words that play different semantic and grammatical roles like referring to a teacher as a *lessoner* (Clark, 1978). The more encounters with words and morphemes in different contexts, the stronger the lexical representations become in memory (Perfetti, 2007). Strategic morphological analysis builds on what was initially learned tacitly, and it also involves a metalinguistic regard for words. Adolescents move from functional use of linguistic units to deliberate analysis and manipulation of linguistic units (Valtin, 1984). Adolescents therefore use representations of morphemes in their mental lexicon to read or figure out the meaning of unknown words (e.g., *treelet*) if they realise that words can be decomposed into units of meaning (Anglin, 1993; Carlisle & Fleming, 2003). While tacit morphological processing builds and speeds access to lexical representations, strategic morphological analysis promotes an analytic approach to understanding and using words, especially through figuring out the many derived and compounded words adolescents encounter in their reading.

## Tacit morphological processing

A closer look at tacit morphological processing shows that root words (i.e., free morphemes) and affixes that are represented in a student's mental lexicon contribute to the processing and spelling of printed words by spreading activation; the surface level (e.g., *lovable*), the root word (e.g., *love*), and affix(es) (e.g., -*able*) contribute to the speed and/or accuracy of responses by students and adults (Feldman, Rueckl, DiLiberto, Pastizzo, & Vellutino, 2002; Frost, Grainger, & Carreiras, 2008; Goodwin, Gilbert, Cho, & Kearns, 2014). Evidence for this tacit morphological processing emerges from studies showing that students read aloud (presented and recorded by a computer) derived words like *hilly* faster and more accurately than pseudo-derived words like *silly* which had been matched for word length, frequency, and spelling (e.g., Carlisle & Stone, 2005). They also read aloud (to a researcher) words with suffixes (e.g., *locked*) more accurately than words with pseudo-suffixes (e.g., *ladder*; Laxon, Rickard, & Coltheart, 1992) and chose the correct spelling of derivational suffixes for two-morpheme words (*lucky*) more often than for one-morpheme words (*candy*; Sangster & Deacon, 2011). The influence of morphological processing cannot be explained by overlap with phonological, orthographic, or semantic features. For example, McCutchen et al. (2009) found that fifth and eighth graders responded more quickly to target words like *assume* when words were primed by a morphologically related word like *assumption* versus when the prime was a semantically (e.g., *expect*) or orthographically (e.g., *assignment*) related word.

This tacit morphological processing depends largely on the quality of the lexical representations that have developed from exposure to words and morphemes (Perfetti, 2007; Reichle & Perfetti, 2003). For example, Carlisle and Stone (2005) found high school students recognised derived words with stable (e.g., *depend-dependence*) and shifting pronunciation (e.g., *nature-natural*) faster than middle schoolers and were similarly fast and accurate on the stable and shift words whereas the middle school students performed less well on the shift words. Low literate adults, who have difficulties with reading, seem to have even more difficulty with morphological processing: they read single morpheme words more accurately than morphologically complex words matched for frequency and length (Tighe & Binder, 2015). It seems that higher quality lexical representations and well-specified associations between morphemes and related morphologically complex words contribute to fluent word identification such that mental processes can largely be devoted to higher level comprehension. These high quality lexical representations likely support vocabulary breadth and depth as well as fluent reading and comprehension of texts.

Tasks that assess tacit morphological processing might assess accuracy or speed of word reading, spelling, or meaning knowledge of morphologically complex words. Ideally, such tasks include examining the relationship between performance on morphemes (i.e., root words like *isolate* or affixes like *ion*) and their application to performance on a related morphologically complex word (i.e., *isolation*), which adds confidence that morphological knowledge has contributed to performance on the morphologically complex word when there is evidence that the student read the morpheme correctly. A main characteristic is that these tasks focus students on a morphologically complex word without explicitly drawing attention to the internal structure of that word.

## Strategic morphological analysis

Literacy experiences and discussions of words and their meanings also help students become more cognizant of the ways that the sound, spelling, and meaning of morphemes contribute to expressions of meaning. This can lead to more strategic, deliberate use of morphological knowledge in reading and writing. Improvements in morphological analysis are based in part on growth of students' vocabulary, but are also related to adolescents' ability to reflect on the content and form of language simultaneously (Anglin, 1993; Van Kleeck, 1982). Conscious morphological analysis likely occurs in settings that encourage analysis of the internal structure of the word, the meanings and grammatical roles of the affixes, and the context in which the word is used. For example, middle school students were better able than elementary students to judge whether corner comes from corn and also choose the appropriate pseudoword with a real suffix to complete a sentence, probably because they were consciously considering the overlap between form and content (Berninger, Abbott, Nagy, & Carlisle, 2010). Anglin (1993) shows this conscious analysis through a fifth grader's efforts to identify the meaning of *priesthood* by first identifying the morphemic constituents (the student was familiar with the word *priest* and remarked that *hood* was in the word *childhood*); the student then faced the problem of trying to determine what the whole word might mean. Similarly, Pacheco and Goodwin (2013) describe a middle schooler's use of morphological analysis to deepen understanding of the word *cavity* from *a bad thing in a tooth* to the more accurate meaning of *a hole in a tooth*.

Strategic morphological analysis may contribute to vocabulary and comprehension differently. For vocabulary, conscious morphological analysis would support vocabulary breadth and depth by deepening the meanings of known words or inferring the meanings of unfamiliar words from familiar morphemic elements (Nagy et al., 2014). Additional supports for comprehension would be expected, as students need to be able to consider the semantic and syntactic roles of the component morphemes that make up unfamiliar words, phrases, and sentences they are reading (Tyler & Nagy, 1990). For example, students reading about 'militant groups' might consider the suffix *-ant* (a person who) and the root word *military* to establish that the text is referring to a group who are armed like the military (Goodwin & Perkins, 2015).

Some tasks used to assess morphological knowledge require strategic analysis by encouraging students to analyse the morphological structure of a word. The problem solving aspect may be presented in the directions, examples, or the items themselves. For example, a morphological judgement task draws students' attention to morphological structure via directions (determine if a second word is *derived* or comes from another) and examples (*corn* and *corner* versus *heal* and *health*). Similarly, sentence completion tasks ask students to select a word or pseudoword that ends with an appropriate suffix to complete a sentence (e.g., suffix tests, Tyler & Nagy, 1989); this draws their attention to the internal structure of words by focusing on the only element that changes within the answer choices—the suffixes. In analysing the internal structure of words (i.e., analysis of root words and affixes), students are encouraged to focus on how the orthography conveys meaning.

## PERSPECTIVES ON DIMENSIONALITY OF MORPHOLOGICAL KNOWLEDGE

While researchers may use tasks that require tacit processing or strategic analysis, they may be assuming that morphological knowledge is a unidimensional construct. The assumption may be that any task of morphological knowledge will provide an understanding of a student's morphological knowledge as it is related to literacy (see Model 1 in Table 1). Identifying the base word in derived words could serve as a measure of students' morphological knowledge (e.g., Carlisle, 1988), but so too could their reading of morphologically complex words made of familiar morphemes (e.g., *shady*, Carlisle & Stone, 2005).

There is some evidence for unidimensionality of morphological knowledge. Muse (2005) (also reported in Wagner, Muse, & Tannenbaum, 2007) administered nine morphological analysis measures to fourth graders, with fit indices suggesting the data fit best as a single latent variable (i.e., a general factor). Muse explored multiple conceptualizations including possible dimensions related to implicit morphological processing and conscious awareness of morphemes; she also used different tasks, such as written versus oral measures and multiple-choice versus production response formats. Her results consistently suggest unidimensionality. Tighe and Schatschneider (2015) similarly explored dimensionality of morphological knowledge, although with low literate adult learners. A single latent variable fit best for most explorations, suggesting unidimensionality related to many task characteristics like derived versus inflected words and context clues versus isolated word presentation. Nagy, Berninger, Abbot, Vaughan, and Vermeulen (2003) and Nagy et al. (2006) provide further evidence as they used multiple morphological analysis measures to create a latent variable representing elementary and middle school students' morphological knowledge.

In contrast, some evidence from studies with multiple morphological measures indicate that morphological knowledge may be multidimensional (e.g., Berninger et al., 2010; Carlisle, 2000; Cho, Gilbert, Goodwin, 2013; Elbro & Arnbak, 1996; Goodwin et al., 2013, 2014). Model 2 in Table 1 shows such relationships. For example, Danish adolescents with dyslexia had greater difficulty on analogy, compound formation, and root word extraction measures (i.e., strategic morphological analysis measures) versus measures of more tacit morphological processing involving reading and spelling morphologically complex words (Elbro & Arnbak, 1996). Studies also suggest that different assessments of morphological knowledge contributed differently to literacy outcomes. Goodwin et al. (2013, 2014) found tacit morphological processing (applying knowledge of root-word reading, spelling, and meaning) and morphological analysis (analysing the internal structure of words) contributed uniquely to derived-word reading and lexical representations. In another study, tacit morphological processing (i.e., a derived word reading test), but not strategic morphological analysis (i.e., where credit for successful defining was given if the fifth graders explained the meaning of the root word and used it correctly in a sentence), made a unique contribution to standardised vocabulary knowledge (Carlisle, 2000). In contrast, the morphological analysis task but not the morphological processing task made a unique significant contribution to reading comprehension. It may be that in addition to types of processing, differences in tasks are important. For example, Tighe and Schatschneider's (2015) work with low literate adults showed that real word and pseudoword tasks made up two dimensions of morphological knowledge, yet this was only found after differences in response types (i.e., free-response vs production) were taken into account.

An alternative way of conceptualising the multidimensionality of morphological knowledge is a bifactor model, wherein morphological knowledge involves students' general sensitivity to the morphological structure of words and a separate set of dimensions that represent unique supports of morphological processing and strategic analysis for various language and literacy tasks (see Model 3 in Table 1). From this perspective, there is a general dimension of morphological knowledge representing what is similar about all the tasks, but there are also specific dimensions representing differences in processing and analysis stemming from the demands of morphological tasks.

If a bifactor model is confirmed, general morphological sensitivity may support vocabulary on the one hand by building automatic recognition of the meaning of many morphologically complex words and, on the other hand, by deepening understandings of the semantic and syntactic aspects of morphologically complex words. Performance related to strategic morphological analysis, though, may contribute to vocabulary uniquely beyond the general factor because a student's analysis of the internal structure of words often is key to inferring the meaning of an unknown word (see *priesthood* example, Anglin, 1993). Similarly, performance on reading comprehension may involve both the general dimension and the specific dimensions of morphological analysis, which would help an adolescent infer the meaning of unknown words necessary for comprehension.

## STUDY PURPOSE AND DESIGN

Our study examines the dimensionality of morphological knowledge framed within the context of possible differences between tacit processing and strategic analysis. We examine (1) the dimensionality of adolescents' performances on categories of morphological knowledge tasks and (2) the extent to which various dimensions within morphological knowledge uniquely contribute to vocabulary and reading comprehension skills for adolescent readers.

## METHOD

### Participants

There were 371 participants (234 seventh graders and 137 eighth graders; 181 males and 190 females) who attended two suburban schools in the southeastern United States (309 School A and 62 School B). Both schools reported grades of A on state standardised tests and served relatively affluent populations (e.g., School A: 11% minority, 5% economically disadvantaged; School B 19% minority; Tennessee Department of Education Report Card, 2011). School A included more morphological instruction, using a Greek and Latin morphemes curriculum (Harris, 2009), whereas School B approached vocabulary instruction through directly teaching words from texts students were reading. Students of 12 teachers participated (7 School A, 5 School B). Students ranged between the second and 99th percentile on standardised reading comprehension and reading vocabulary tests, averaging the 72nd percentile on each.

### Procedure

This study involves analysis of students' performance on morphological knowledge and literacy measures from an earlier study (Goodwin, Gilbert, & Cho, 2013) and on a larger battery of morphological knowledge assessments administered for this study and another (Goodwin et al., 2014). Unlike the prior study, which focused on development of lexical representations, this study makes an important unique contribution by exploring the dimensionality of the morphological knowledge tasks. Consent procedures were similar at each school. Snow days (i.e., days where the amount of snow cancelled school) made it impossible to administer the full battery to all students, so a subsample of students took as many assessments as possible during shortened class periods. To minimise priming of visual forms, derived-word aspects of each measure were administered before root-word measures. Also, the morphological spelling, meaning, and analysis measures were administered before the morphological word reading measures. Assessments were administered by teams of study personnel trained in two practice sessions and then required to observe implementation of the assessments prior to independent administration.

## Measures

A battery of seven written morphological measures and two standardised tests of reading vocabulary and reading comprehension were administered. All were group administered except the morphological word reading measure. Four of the measures were based on tasks used by other researchers, but we held the content constant by using the same 40 root words and their derived counterparts (see Appendix A and Goodwin et al., 2013 for more information). This list was developed after consulting studies of the types of words found in adolescent academic texts, which include morphologically complex words of Latin and Greek origin (Bar-Ilan & Berman, 2007; Nagy & Anderson, 1984; Nagy & Townsend, 2012). The list was purposefully varied, considering what Nagy and Anderson (1984) termed the 'great variety of types and degrees of relatedness among words' (p. 306). We primarily included derivations that differed in the closeness of the relationship between the root word and affixes (i.e., *tranquil* and *tranquility* vs. *quest* and *unquestionably*) and in the frequency and amount of meaning conveyed by affixes. Words in this list ranged from 2 to 5 morphemes; the mean frequencies of the derived and root words were 37.80 and 45.511 respectively (Zeno, Ivens, Millard, & Duvvuri, 1995). About 46% of the words were phonologically opaque, 26% were both orthographically and phonologically opaque, and 31% were semantically opaque. Table 2 reports measure information, including example items, reliabilities, means, and number of items.

**Strategic morphological analysis—**To assess strategic use of morphological knowledge, tasks were used that encouraged students to consider the internal structure of words. Rather than presenting just a derived word or root word, each task focused students' attention on the morphological makeup of words by drawing attention to root-words or affixes as they related to larger morphologically complex words. All tasks were read aloud, although participants were allowed to proceed at their own pace.

**Suffix choice (pseudoword and real word tasks)—**The two suffix choice subtests focused on students' ability to choose from a set of options either the suffixed word or pseudoword that most accurately completed each sentence. Students' attention was drawn to suffixes as that was what changed within the answer choices. Pilot testing suggested the need to use pseudoword items from Singson et al. (2000) and harder real word items from Mahony (1994). Suffixes turned root words into nouns (e.g., -*ist*, -*ion*/-*ation*, -*ity*, and -*ness*), verbs (e.g., -*ate*, -*ise*, and -*ify*), or adjectives (e.g., -*ous*/-*ious*, -*al*, and -*ive*).

**Morphological judgement task (comes from task)—**Using the 24 highest frequency of 42 original items from Mahony (1994), we asked participants to analyse the internal structure of words and determine whether pairs of words were morphologically related (e.g., *add* and *additive*) or not (e.g., *alto* and *altogether*). Students could also respond, 'I don't know' to minimise guessing.

**Generate morphologically related words—**Adapted from the Academic Vocabulary and Spelling Inventory (AVSI; Flanigan et al., 2011), participants analysed a morphological family's overlap by writing down as many morphologically related words (i.e., words that shared the same root word) as possible. The example of *forget* was provided; related words were *forgetful*, *forgetting*, *forgettable*. Students were cautioned that words which conveyed the definition (e.g., *not remember*) were not morphologically related because they did not share the root *forget*. Responses were scored based on quantity and accuracy (no correct responses, value of 0; 1 or more correct responses, value of 1). Following Reichle and Perfetti (2003), correct responses included derivations, inflections, and compounds; students received credit for any phonologically plausible responses.

**Tacit morphological processing—**To confirm the likelihood that morphological knowledge was used when processing a given derived word, we used processing measures that related performance on root words to performance on a derived form of the word. Root word and derived word content were presented separately (at different times) so students' attention was focused on whole words rather than the morphemes within the words. Evidence suggests that by middle school readers have 'encapsulated word representations in which a word's orthographic form contains the word's phonological and semantic information… [and therefore] do not consciously rely on morphological information' (Gilbert et al., 2014, p. 40) when processing whole words.

**Morphological word reading processing—**Students read a list of derived words followed by a list of related root words; responses were recorded. Research team members analysed the audio files, scoring responses as correct (value of 1) if the student correctly pronounced both the root word and the related derived word or incorrect (value of 0) if the related root word or derived word was pronounced incorrectly based on legal dictionary pronunciations or allowable differences because of dialect variation.

**Morphological spelling processing—**This measure assessed students' ability to spell derived words and their related root words when presented in isolation. A research team member read aloud a list of derived words followed by a list of root words; words were scored as correct (value of 1) if the student correctly spelled both the root-word and the related derived-word or incorrect (value of 0) if the related root-word or derived-word was spelled incorrectly.

**Morphological meaning processing (self-perceived)—**Participants rated their knowledge of a list of derived words followed by a list of related root words, choosing whether they had no knowledge, some knowledge, or full knowledge of the meaning of each member of the 40 word pairs. Previous research provided evidence of the validity of this group-administered measure (Tyler & Nagy, 1989). Participants were given the example of *forget* and were shown how knowledge of this word might be classified. Each word was read aloud by the test administrator. Responses were scored as correct (value of 1) if the participant reported some or full knowledge of both the root word and the related derived word or incorrect (value of 0) if no knowledge of the root or the derived word was reported.

### Standardised literacy measures

**Reading comprehension—**The Gates-MacGinitie Standardized Test of Reading Comprehension (MacGinitie, MacGinitie, Maria, & Dreyer, 2000) was used to assess reading comprehension via Form S of Level 7 through 9. The measure consisted of 11 passages with 48 multiple choice comprehension questions. Extended scale scores were used.

**Vocabulary knowledge—**The Gates-MacGinitie Standardized Test of Reading Vocabulary (MacGinitie et al., 2000) was used to assess reading vocabulary knowledge. Participants read an underlined word within a phrase and then selected the word or phrase that means most nearly the same. The 45 items on form S of Level 7 through 9 were administered. Extended scale scores were used.

## Data analysis

Given the large pool of items from the pilot testing ($n = 229$), we first conducted an item analysis to evaluate poorly functioning or redundant items. The goal was to reduce each subscale to relatively few items such that a reduced battery would maintain or improve upon the base level reliability of each subscale. Two primary pieces of data were used to render decisions concerning item culling: the alpha-if-deleted index and item-total correlations. Items were deleted if they presented with one or more of the following criteria: (1) an equivalent or higher alpha-if-deleted index compared to the base reliability coefficient, (2) a negative item-total correlation, or (3) an item-total correlation < .15.

Once we culled our pool of items, we explored the dimensionality of morphological knowledge via confirmatory factor analysis (CFA) as shown in Table 1. Each model consisted of a combination of a *general factor*, a term we use to refer to the latent variable representing the general construct of morphological knowledge stemming from overlap of the seven morphological measures, and/or *specific factors*, a term we use to refer to each of the hypothesised dimensions representing elements of morphological knowledge unique from the general factor. Based on the literature, we created two hypothesised combinations of specific factors. Models we labelled as TACIT&STRATEGIC had two specific factors representing morphological tacit processing (indicated by morphological spelling, word reading, and meaning processing tasks combined) and morphological strategic analysis (indicated by tasks involving analysis of the internal structure of words). Alternatively, models we labelled as TASK consisted of seven specific factors representing the unique demands of each morphological task (representing different aspects of morphological knowledge such as morphological reading, morphological spelling, morphological meaning, consideration of morphological overlap, analysis of the role of suffixes in real words and in pseudowords, and generation of morphologically related words).

In all, six measurement models were evaluated: (1) a one-factor (i.e., UNIDIMENSIONAL) model of morphological knowledge where the general factor represented overlap of the items from the seven observed measures (i.e., a general morphological knowledge factor), (2) a two-factor (TACIT&STRATEGIC) model with specific factors of strategic morphological analysis and tacit morphological processing, (3) a seven-factor (TASK) model with specific factors for each of the tasks, (4) a second order, seven-factor (second order, TASK) model with specific factors for each task and a second-order factor (representing overlap of the latent composites or general morphological knowledge), (5) a two-factor bifactor (bifactor TACIT&STRATEGIC) model with specific factors representing strategic morphological analysis and tacit processing and an additional general factor of morphological knowledge, which was measured by the seven manifest variables, and (6) a seven-factor bifactor (bifactor TASK) model with specific factors representing each task and an additional general factor of morphological knowledge.

The bifactor model is conceptually similar to a second-order measurement model because an additional factor is modelled above that of the primary theoretical latent constructs. What differentiates the bifactor model is where the general factor appears. The second-order construct is indicated by the first-order specific factors and thus models the common variance amongst first-order latent factors. Conversely, a bifactor model views the primary latent factors as specific factors related to the skills being measured, and the additional factor (the general factor) is fit to the observed measures; thus, the specific factors represent sources of variance amongst the indicators above that captured by the general factor (Reise, Morizot, & Hays, 2007). An additional distinction between the second-order and bifactor models is that the bifactor model allows testing of whether variance across the observed measures is because of a general factor, such as morphological knowledge, or because of specific factors of morphological knowledge like strategic morphological analysis and tacit morphological processing. The second-order specification does not allow for such estimation because the higher order construct is capturing the common variance in the first-order factors and not the observed measures.

Finally, the bifactor model allows for testing the extent to which the general and specific factors uniquely predict proximal or distal outcomes. The specification of the bifactor model requires that the specific factors of morphological knowledge are uncorrelated. This achieves several purposes; by specifying the orthogonality of the specific and general factors, the specific factors represent what is uniquely measured by the respective constructs after controlling for what is shared by the general factor. Therefore, in a subsequent structural analysis, it is possible to determine whether the specific components uniquely relate to the vocabulary and reading comprehension tests, after controlling for what is shared between them.

Model fit for the measurement comparisons was conducted using Akaike Information Criteria (AIC) and the sample-size adjusted Bayes Information Criteria (ABIC). Although several hypothesised models were nested, the literature is mixed as to whether bifactor models are nested versions of multidimensional models. As such, we opted to use AIC and the ABIC for relative fit comparisons with smaller values for AIC and ABIC desired (Raftery, 1995). Models were also evaluated with the comparative fit index (CFI, Bentler, 1990), Tucker–Lewis index (TLI; Bentler & Bonnett, 1980), and the root mean square error of approximation (RMSEA, Browne & Cudeck, 1992). CFI and TLI values $\geq 0.95$ are minimally sufficient criteria for acceptable model fit, and RMSEA and SRMR estimates $< 0.05$ are desirable, with up to .10 considered acceptable. All models were run with the culled item set and then confirmed with the entire set of items. Our final modelling decisions took into account the fit statistics of the best fitting models (both with the culled and full item set) and also relationship to theory. Once our measurement model was established, we then explored the relationship between the suggested dimensions of morphological knowledge and standardised literacy outcomes (i.e., vocabulary and reading comprehension) using Structural Equation Modelling. All analyses were run in Mplus 7.2 (Muthén & Muthén, 2013).

## RESULTS

### Preliminary data analysis

Descriptive results for experimental measures are presented in Table 2. The mean score for reading comprehension and vocabulary was 561.01 ($N$ = 358; $SD$ = 35.42) and 558.50 ($N$ = 358; $SD$ = 32.54) respectively. As described, there were different amounts of missing data because of inclement weather, ranging from 20% for the suffix choice and morphological judgement tasks to 58% for the generating morphologically related words task. While the data were not missing completely at random (i.e., MCAR, Little's test of data missing completely at random; $\chi^2(92) = 194.86$, $p < .001$), a review of the data suggested that missingness patterns were not because of the variables themselves. In other words, the data were missing at random because the reason for missingness was weather (i.e., snow) NOT item or participant characteristics. We were guided by the psychometric literature in our approach to missingness: we leveraged full information maximum likelihood estimation (FIML) in the latent variable analyses because studies suggest that less bias is present when analyses involve data from the full sample of participants versus only including data from the sub-sample with full data on all measures (Enders, 2010). Because our data were missing at random, FIML and multiple imputation (MI) give the same result (e.g., Collins, Schafer, & Kam, 2001). Correlations of performance on the experimental and standardised measures are presented in Table 3 with correlations provided for the full item set below the diagonal and correlations for the culled item set provided above the diagonal. The strongest associations were observed between measures that shared the same format but differed in content (i.e., the real word and pseudoword suffix choice tasks, $r$ = .75, .67).

### Item reduction

Table 2 reports the results of the reliability analysis of the response matrix for the full item set and the culled item set. All full item set estimates of Cronbach's α for internal consistency were above .85 except for the MJT task, which had a reliability of .57. By evaluating the alpha-if-deleted index and the item total correlations, 10 items were dropped from MJT increasing the reliability to α = .68. Also, 16 items were dropped from SCR resulting in α = .90; 9 items were dropped from SCP for α = .82; 24 items were dropped from GMRW resulting in α = .90; 20 items were dropped from MSPELL resulting in α = .88; 21 items were dropped from MMEAN resulting in α = .87; and 23 items were dropped from MREAD for a α = .83. In total, item culling removed 124 items without significantly altering the internal consistency of the item responses. By reducing the overall item total bank from 230 to 106, a better item-to-person ratio was maintained which increased the precision of the standard errors for the latent variable modelling and improved the run-time for the model algorithms. Correlations amongst the total scores from the reduced subscales are reported on the upper diagonal of Table 3.

### Measurement model

Summary results for the measurement specifications are reported in Table 4. The UNIDIMENSIONAL model [$\chi^2(5,459) = 6{,}270.66$, CFI = .89, TLI = .89, RMSEA = .02 (95% CI = .017, .022), AIC = 22696.51, ABIC = 22854.14] indicated that a general factor of morphological knowledge did not fit well. When comparing the criterion and relative fit indices across models, the two best fitting specifications were the seven-factor model (TASK) [$\chi^2(5,438) = 5{,}593.38$, CFI = .98, TLI = .98, RMSEA = .009 (95% CI = .000, .013), AIC = 21598.22, ABIC = 21771.46] and the seven-factor-bifactor (bifactor TASK) model [$\chi^2(5,353) = 5{,}575.02$, CFI = .97, TLI = .97, RMSEA = .011 (95% CI = .005, .014), AIC = 21748.85, ABIC = 21985.29]. Results with the full sample echoed these findings of excellent fit, although suggesting that the seven-factor-bifactor (bifactor TASK) model might be superior based on AIC and ABIC values [seven-factor model AIC = 46525, BIC = 48409; seven-factor-bifactor model AIC = 46508, ABIC = 47021].

These similar, yet different results led us to embrace theory to guide us in further unraveling the statistics to determine our final measurement model. As discussed in the literature review, theory and research suggest a common set of core elements are tapped by different morphological tasks. Therefore, we looked more closely at results related to overlap or shared variance in each model. A main difference between the two models is where the overlap amongst tasks is modelled (i.e., in the seven-factor TASK model, the overlap is modelled as correlations amongst the specific factors whereas in the seven-factor-bifactor model or bifactor TASK model, the overlap is modelled in the general factor and then the specific factors are modelled as unique). In the seven-factor (TASK) model, the specific factors were strongly correlated with 19 out of the 21 correlations being greater than .45 and seven of the correlations being greater than .70 (see Table 5). This suggests that, in reality, the specific factors were not as unique as the seven-factor (TASK) model suggested. In fact, the strength of the correlations amongst the specific factors may have masked the ability to evaluate the relative exogeneity of each factor. We then examined the standardised factor loadings (presented in Appendix B) of each item on the generalised morphological knowledge factor within the seven-factor-bifactor (bifactor TASK) model. These highlight that the relation between the strength of the item loadings relative to the morphological knowledge versus the strength of the item loadings relative to the specific factor itself. Loadings greater than 0.4 between the item and the general factor would suggest overlap with the general factor. Over 90% of loadings met that criterion, again suggesting important overlap amongst the items across tasks. Based on these considerations, we settled upon the seven-factor bifactor (bifactor TASK) model as the best fitting model because it showed excellent fit to the data and most clearly communicated the overlap present amongst all the morphological items from the seven morphological tasks.

It is important to note that the seven-factor-bifactor (bifactor TASK) model allowed different tasks to vary in their relationship to the general morphological knowledge factor (i.e., there was some general overlap, but there were also unique differences reflected in the specific factors). For example, Appendix B shows that items on the MMEAN task (i.e., morphological meaning processing task) were less related to the general factor, yet more closely related to the specific factor than the other tasks. Similarly, the GMRW task (i.e., generating morphologically related words) items maintained strong associations with the specific factor of GMRW controlling for the strong relationship between the GMRW items and the general factor. Conversely, items on the MJT (i.e., morphological judgement task) were more weakly associated with that specific factor compared to the general morphological knowledge factor. Across the seven tasks, only the GMRW and MMEAN items generally maintained stronger associations with the specific factor compared to the morphological knowledge factor. Such evidence points to task-specific items sharing greater variance with other items across multiple tasks compared to within-task items, again providing evidence for the seven-factor-bifactor (bifactor TASK) model (Figure 1).

### Structural analysis

From the bifactor model, the seven specific factors along with the general factor of morphological knowledge were used to test the predictive validity of the factors in understanding individual differences in reading comprehension and reading vocabulary. The standardised coefficients from this model are displayed in Figure 2. The *SEM* model provided excellent fit to the data [$\chi^2(5550) = 5784.14$, CFI = .97, TLI = .97, RMSEA = .011 (95% CI = .005, .014)]. The estimates suggest that the general morphological knowledge factor most strongly predicted reading comprehension (.70), with small, unique effects observed for morphological reading (.20), morphological spelling (.17), and morphological meaning (.19); 61% of the variance in reading comprehension was explained by the factors. For the vocabulary outcome, the general morphological knowledge factor maintained the strongest association (.76) with small, unique effects of morphological generation of root words (.13), morphological spelling (.16), and morphological meaning (.20); 69% of the variance in vocabulary was explained by the latent factors.

## DISCUSSION

The dimensionality of morphological knowledge is important to understand when interpreting current theory, research, and practice. Results of our study indicated that morphological knowledge is best considered a multidimensional construct represented by a general construct (i.e., a general morphological knowledge factor) and seven dimensions (i.e., specific factors) that signify different morphological skills or knowledge assessed by different tasks. Although we had hypothesised that our seven tasks would represent two morphological knowledge dimensions related to tacit processing and strategic analysis, results did not confirm this. Instead, the seven tasks could not be reduced to a smaller number of dimensions, suggesting that the different tasks used to assess morphological knowledge involve common morphological processing mechanisms, but also tap important differences in performance beyond tacit processing and strategic analysis. Differences were indicated related to different morphological subskills like root word processing within morphological reading, morphological spelling, morphological meaning, as well as consideration of morphological relationships, analysis of the role of suffixes in real words and in pseudo-words, and generation of morphologically related words. These results raise questions about the tendency to view morphological knowledge as *either* unidimensional (all tasks similarly represent morphological knowledge; Muse, 2005) or multidimensional (different tasks represent independent categories of morphological knowledge tasks; Tighe & Schatschneider, 2015). Instead, an alternative view is suggested.

The first main component of morphological knowledge suggested by our study involves a core set of knowledge that highlights the presence of meaningful units within words; these understandings can be applied to various literacy areas and are involved in any assessment of morphological knowledge. For example, a student would likely use the morphological structure of a word like *detective* when attempting to spell, read, or ascertain its meaning. The student would use morphological understandings to consider the root word, *detect*, the suffix *ive*, or related words detection, detecting, detects, detection, detector, detected, etc. He may think about the overlap in meaning, spelling, or pronunciation or other word-formation rules. The general factor found in our study is similar to the single dimension found in others (Kieffer & Lesaux, 2012; Muse, 2005; Tighe & Schatschneider, 2015) where no additional dimensions were noted for different types of tasks like oral versus written tasks or multiple-choice versus production (Muse, 2005) or context versus isolated word or tasks with derived versus inflected words (Tighe & Schatschneider, 2015). This general factor seems to represent sensitivity to a word's morphological structure.

The second component involves specific dimensions (i.e., specific factors) that represent different aspects of morphological knowledge that can be applied in different ways to support performance in different areas of literacy. These specific understandings go beyond understanding morphological structure and instead include specific skills that can develop separately. For example, a student reading *detective* may engage knowledge of morphological rules like how the suffix *ive* is pronounced differently in *detective* than within single morpheme words like *hive*. This is different from the skills used to figure out the meaning of *detective*, where the same student may focus more on the meaning and syntactical role of the suffix *ive* rather than its pronunciation. The student may further apply skills like considering the meaning of *detect* or linking to the larger morphological family to determine the meaning of *detective*. This multidimensionality related to different tasks is suggested in the literature as Tighe and Schatschneider (2015) noted differences between pseudoword and real word tasks and also possible differences between multiple-choice and free-response tasks. Similarly, Kieffer and Lesaux (2012) indicated distinctions related to task features within four morphological knowledge tasks. Neither of these studies examined a bifactor model that allowed for possible overlap and also distinctive dimensions, highlighting the contribution of our study. Our results suggest that although the skills assessed by the tasks in our study share an understanding of morphological structure, they also involve unique understandings that can develop and be applied in different ways.

## Contributions to reading comprehension and vocabulary

Predictive validity related to vocabulary and reading comprehension was also explored. Attending to dimensionality had important consequences as the combination of the seven morphological tasks (i.e., the combination of the general factor and the seven specific factors) explained a large amount of variance in each literacy outcome. These results confirm findings from prior research that suggest that morphological knowledge is closely related to vocabulary and reading comprehension (Carlisle & Goodwin, 2013; Nagy et al., 2006). Most of this variance was associated with the general factor, which represented core elements of morphological knowledge tapped by all seven morphological tasks. The general factor made a large and meaningful contribution to standardised vocabulary and reading comprehension. Considering morphological overlap in meaning, spelling, or pronunciation helped adolescents build more high quality lexical representations that then aided reading comprehension efforts.

Of interest is that solely considering overlap in tasks would likely miss unique contributions of dimensions (i.e., specific factors) of morphological knowledge, beyond the contribution of the general factor. This means that including tasks that tap these different aspects of morphology help to unravel the relationship between morphological knowledge and different literacy outcomes. Our results suggest that knowing the meaning of more derived words (given knowing that word's root word) and being able to generate morphologically related words for a target word supports vocabulary knowledge beyond general morphological sensitivity (i.e., the general factor). Students with these skills either build more high quality lexical representations across time or are better able to problem-solve the meanings of unfamiliar words using knowledge of a root word or additional morphological relatives. As such, considering words within morphological families seems to support general vocabulary knowledge.

In contrast, morphological spelling processing had a negative relationship with vocabulary controlling for the other variables in the model. This signifies that beyond the general factor (i.e., sensitivity to the morphological structure of words), overly focusing on spelling may hinder vocabulary knowledge. Here, the bifactor model results should be interpreted carefully as morphological spelling processing is part of the general factor, which did support vocabulary knowledge in a large way. What our results suggest is that the general factor may be assessing consideration of overlap between form and meaning, which would include recognising transparent overlap in spelling like between *know* and *knowledge*. It may be that the specific factor is isolating an overreliance on morphological spelling processing while not considering overlap in meaning. Because morphological relationships are often conveyed opaquely in English, overly focusing on spelling may get in the way of vocabulary knowledge. For example, when determining the meaning of *provision*, the change in spelling between *provide* and *provision* may hide the morphological overlap, instead suggesting overlap with units like *pro* or *vision*. Our results highlight the different application of morphological skills to different literacy tasks. Also, neither the suffix tasks, the morphological judgement task, nor the morphological reading task supported vocabulary skills beyond the general factor, which indicates that the primary support for vocabulary in those tasks was in applying general morphological sensitivity or knowledge of the presence of meaningful units within words to vocabulary knowledge.

In terms of reading comprehension, beyond the general factor, only morphological meaning processing provided support. Here it seems that general sensitivity to morphological structures was most important in supporting reading comprehension, with additional morphological meaning knowledge providing further supports likely because this extra derived word knowledge could be applied to support reading comprehension endeavors beyond general morphological sensitivity. Beyond considering morphological overlap, applying meaning knowledge of a root word or suffix seems to help reading comprehension. On the other hand, both morphological spelling and morphological reading tasks had a negative relationship with reading comprehension, but this may be related to the age of our participants. As Gilbert et al. (2014) point out, it may be that by 7th and 8th grade, lexical representations have become modular such that a word's orthographic form activates information about the word instantaneously. Therefore, perhaps overly focusing on morphemes pronunciation (morphological word reading processing) or orthographic form (morphological spelling processing) when it is not needed may make it hard to focus on meaning or comprehension.

### Limitations and future research

Our study is the first attempt to fit this model and more research perhaps including other item level data should be done to replicate our findings. Also, our study involves theoretically identified dimensions; therefore, it would be beneficial for other studies to investigate the relations of tasks and dimensions using other theoretical frameworks and exploratory factor analyses. For example, future research should examine other possible dimensions of morphological awareness not included within our study such as morphosyntactic knowledge (i.e., knowledge of the grammatical role of morphemes, Tong, Deacon, & Cain, 2014; Tyler & Nagy, 1989) and cognate awareness (i.e., awareness that words in multiple languages share orthographic and semantic characteristics like *rapid* and *rápido*; Jiménez, García, & Pearson, 1996), as well as other possibilities. This exploration might take age, reading level, and/or language background of students into account as the relationships between tasks may differ for different readers. For example, whereas our study found that morphological meaning processing was uniquely positively associated with reading comprehension beyond the relation of the general factor for adolescent readers, a study with younger students or struggling word readers may find morphological word reading processing may play a significant role in reading comprehension beyond the role of the general factor because of the importance of word reading at that developmental point and for struggling readers. Such relationships have yet to be explored in this manner.

Another important area to consider in future research is the relation between content and task. Four of our seven morphological measures involved the same set of words, suggesting the need to replicate with different content. Also, our tasks included various morphological forms (i.e., inflections, derivations, compounds, or a combination of those), different morphological word parts (i.e., free or bound roots, prefixes, suffixes), and variation in lexicality (i.e., complex words, simple words, or pseudowords). The morphological content also differed in transparency of how the units were combined (i.e., phonological, orthographic, and semantic transparency), frequency of the units involved (i.e., frequency of the base, the complex word, and the morphological family), and length (i.e., number of morphemes). Studies such as Goodwin et al. (2013) have shown that transparency can affect how students apply morphological knowledge to word reading, and therefore, it is important to unravel the relationship between content and task. For instance, if the content is inflections or compounds, do the tasks fall into the same categories? And are they likely to be related to outcomes such as reading comprehension?

A challenge in our study involved missing data. We were fortunate that the psychometric literature included guidelines for dealing with missing data and therefore, we were able to leverage FIML estimation to estimate this missing data within our analyses and gain trustworthy results (Enders, 2010). We also encountered challenges related to priming because we had to administer multiple assessments to determine what students knew about morphological knowledge at a single point in time. We hope future studies will replicate our findings with less missing data and different priming choices.

### Summary

Overall, our study takes an important first step of identifying the dimensionality of morphological knowledge based on performance on tasks designed to tap application of morphological knowledge to different literacy areas. Our results suggest that morphological knowledge can best be understood as a general construct and specific dimensions that represent distinctive morphological skills that have unique relationships to different literacy skills. For adolescent readers, it seems that the general factor that represents a student's general ability to use, identify, and manipulate morphemes within words is particularly important for facilitating vocabulary knowledge and reading comprehension. Applying morphological knowledge to derived word meanings is also helpful in supporting reading comprehension and vocabulary, while generating morphologically complex words, or thinking about words within morphological families, is helpful in building vocabulary knowledge. For adolescents, it seems that lexical entries are becoming modular, and therefore having to use morphological information to support word reading and spelling of derived words was negatively related to reading comprehension and vocabulary, suggesting overuse of mental resources on code-type work versus more comprehension and meaning-related work. Our study suggests that considering dimensionality is likely to lead to more accurate assessment of morphological knowledge and deeper understandings of the mechanisms underlying the contributions of morphological knowledge to literacy achievement.

## Acknowledgements

This research was made possible through startup funding from Vanderbilt University's Peabody College. We thank the students and teachers who participated in the study. Dr. Petscher's time was supported by the Institute of Education Sciences R305F100005 and P50HD052120 from the National Institute of Child Health and Human Development.

## Appendix A. List of overlapping content contained within processing measures

| Root words | Derived words |
|---|---|
| out | outsource |
| economy | economical |
| expedite | expeditious |
| strict | restriction |
| convene | convention |

| Root words | Derived words |
|---|---|
| sphere | thermosphere |
| perceive | perception |
| covet | covetousness |
| diagnose | diagnostician |
| scribe | circumscribe |
| phone | phonetic |
| quest | unquestionably |
| migrate | migratory |
| state | reinstate |
| meter | biometric |
| dorm | dormant |
| discrete | discretionary |
| enchant | disenchantment |
| graph | telegraph |
| tranquil | tranquility |
| strategy | stratagem |
| dictate | dictator |
| distinct | distinguish |
| reside | residence |
| sign | significance |
| finance | financially |
| relative | irrelevant |
| benefit | benefactor |
| aqua | aquascape |
| verify | veritable |
| sense | hypersensitivity |
| genuine | disingenuous |
| usurp | usurpatory |
| irate | irascible |
| nation | nationalistic |
| compose | composite |
| extreme | extremity |
| sage | sagacity |
| precede | precedent |
| malign | malignant |

## Appendix B. Item loadings for bifactor confirmatory factor analysis

| | GMRW | | MJT | | SCP | | SCR | | MREAD | | MSPELL | | MMEAN | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Item** | **MK** | **GMR** | **MK** | **MJT** | **MK** | **SCP** | **MK** | **SCR** | **MK** | **MREAD** | **MK** | **MSPELL** | **MK** | **MMEAN** |
| Item 1 | 0.43 | 0.86 | 0.47 | 0.35 | 0.58 | 0.46 | 0.55 | 0.71 | 0.54 | 0.39 | 0.56 | 0.35 | 0.26 | 0.65 |
| Item 2 | 0.51 | 0.39 | 0.61 | 0.40 | 0.65 | 0.36 | 0.72 | 0.65 | 0.55 | 0.24 | 0.50 | 0.37 | 0.50 | 0.58 |
| Item 3 | 0.53 | 0.68 | 0.41 | **0.08** | 0.69 | 0.46 | 0.61 | 0.68 | 0.68 | **0.16** | 0.57 | 0.56 | 0.35 | 0.41 |
| Item 4 | 0.55 | 0.56 | 0.27 | 0.51 | 0.66 | 0.49 | 0.74 | 0.57 | 0.50 | 0.52 | 0.65 | **0.27** | 0.44 | 0.47 |
| Item 5 | 0.44 | 0.57 | 0.53 | 0.35 | 0.77 | 0.27 | 0.66 | 0.53 | 0.61 | 0.22 | 0.68 | **0.11** | 0.45 | 0.43 |
| Item 6 | 0.71 | 0.55 | 0.58 | 0.44 | 0.72 | **−0.03** | 0.68 | 0.60 | 0.51 | 0.48 | 0.74 | **0.01** | 0.34 | 0.60 |
| Item 7 | 0.53 | 0.76 | 0.30 | 1.09 | 0.54 | 0.64 | 0.75 | 0.50 | 0.54 | 0.32 | 0.70 | 0.30 | 0.55 | 0.60 |
| Item 8 | 0.62 | 0.52 | 0.53 | 0.42 | 0.62 | 0.43 | 0.76 | 0.56 | 0.60 | 0.29 | 0.76 | **−0.14** | 0.28 | 0.63 |
| Item 9 | 0.60 | 0.56 | 0.52 | 0.61 | 0.70 | 0.33 | 0.75 | 0.52 | 0.66 | 0.50 | 0.63 | **0.23** | 0.50 | 0.64 |
| Item 10 | 0.49 | 0.82 | 0.42 | **0.16** | 0.63 | 0.35 | | | 0.66 | 0.30 | 0.68 | 0.29 | 0.57 | 0.56 |
| Item 11 | 0.66 | 0.41 | 0.44 | 0.34 | 0.69 | **0.16** | | | 0.57 | 0.48 | 0.70 | 0.39 | 0.18 | 0.52 |
| Item 12 | 0.65 | 0.58 | 0.60 | 0.29 | | | | | 0.47 | 0.52 | 0.61 | 0.47 | 0.45 | 0.52 |
| Item 13 | 0.44 | 0.45 | 0.41 | **0.16** | | | | | 0.40 | 0.30 | 0.57 | **0.15** | 0.21 | 0.70 |
| Item 14 | 0.48 | 0.57 | 0.49 | **0.25** | | | | | 0.36 | 0.46 | 0.49 | **−0.01** | 0.53 | 0.63 |
| Item 15 | 0.59 | 0.64 | | | | | | | 0.51 | 0.31 | 0.59 | **0.17** | 0.29 | 0.87 |
| Item 16 | 0.55 | 0.44 | | | | | | | 0.51 | 0.38 | 0.56 | 0.30 | 0.51 | 0.50 |
| Item 17 | | | | | | | | | 0.60 | 0.31 | 0.48 | **0.18** | 0.40 | 0.56 |
| Item 18 | | | | | | | | | | | 0.69 | **0.26** | 0.41 | 0.41 |
| Item 19 | | | | | | | | | | | 0.78 | **−0.03** | 0.73 | 0.53 |
| Item 20 | | | | | | | | | | | 0.87 | **0.31** | | |

*Note:* MK= morphological knowledge; nonsignificant loadings in bold.

## References

American Educational Research Association. American Psychological Association. National Council on Measurement in Education. Standards for educational and psychological testing. American Educational Research Association; Washington, DC: 2014.

Anglin JM. Vocabulary development: A morphological analysis. Monographs of the Society for Research in Child Development. 1993; 58:1–186.

Bar-Ilan L, Berman RA. Developing register differentiation: The Latinate-Germanic divide in English. Linguistics. 2007; 45(1):1–35.

Bentler PM. Comparative fit indexes in structural models. Psychological Bulletin. 1990; 107:238–246. [PubMed: 2320703]

Bentler PM, Bonnett DG. Significance tests and goodness of fit in the analysis of covariance structures. Psychological Bulletin. 1980; 88:588–606.

Berninger VW, Abbott RD, Nagy W, Carlisle J. Growth in phonological, orthographic, and morphological knowledge in grades 1 to 6. Journal of Psycholinguistic Research. 2010; 39:141–163. DOI:10.1007/s10936-009-9130-6. [PubMed: 19826956]

Bialystok E, Mitterer J. Metalinguistic differences among three kinds of readers. Journal of Educational Psychology. 1987; 79:147–153.

Bialystok E, Ryan EB. Towards a definition of meta-linguistic skill. Merrill-Palmer Quarterly. 1985; 31:229–251.

Browne MW, Cudeck R. Alternative ways of assessing model fit. Sociological Methods Research. 1992; 21:230–258.

Carlisle JF. Knowledge of derivational morphology and spelling ability in fourth, sixth, and eighth graders. Applied Psycholinguistics. 1988; 9(3):247–266.

Carlisle JF. Awareness of the structure and meaning of morphologically complex words: Impact on reading. Reading and Writing: An Interdisciplinary Journal. 2000; 12:169–190.

Carlisle JF, Fleming J. Lexical processing of morphologically complex words in the elementary years. Scientific Studies of Reading. 2003; 7(3):239–253.

Carlisle, JF., Goodwin, AP. Morphemes matter: How morphological knowledge contributes to reading and writing. In: Stone, CA.Silliman, ER.Ehren, BJ., Wallach, GP., editors. Handbook of language and literacy: Development and disorders. 2nd edn. Guilford Press; New York: 2013. p. 265-282.

Carlisle JF, Stone C. Exploring the role of morphemes in word reading. Reading Research Quarterly. 2005; 40(4):428–449.

Cho SJ, Gilbert JK, Goodwin AP. Explanatory multidimensional multilevel random item response model: An application to simultaneous investigation of word and person contributions to multidimensional lexical quality. Psychometrika. 2013; 78(4):830–855. DOI:10.1007/s11336-013-9333-5. [PubMed: 24092491]

Clark, EV., Sinclair, A., Jarvella, R., Levelt, WJM. The child's conception of language. Springerverlag; New York: 1978. Awareness of language: Some evidence from what children say and do; p. 17-43.

Collins LM, Schafer JL, Kam CM. A comparison of inclusive and restrictive strategies in modern missing data procedures. Psychological Methods. 2001; 6:330–351. [PubMed: 11778676]

Coxhead A. A New Academic Word List. TESOL Quarterly. 2000; 34:213–238.

Deacon SH, Bryant PE. This turnip's not for turning: Children's morphological knowledge and their use of root morphemes in spelling. British Journal of Developmental Psychology. 2006; 24:567–575.

Elbro C, Arnbak E. The role of morpheme recognition and morphological knowledge in dyslexia. Annals of Dyslexia. 1996; 46:209–240. [PubMed: 24234273]

Enders, CK. Applied missing data. Guilford Press; NY, NY: 2010.

Feldman LB, Rueckl J, DiLiberto K, Pastizzo M, Vellutino F. Morphological analysis by child readers as revealed by the fragment completion task. Psychonomic Bulletin and Review. 2002; 9:529–535. [PubMed: 12412893]

Flanigan, K., Hayes, L., Templeton, S., Bear, DW., Invernizzi, M., Johnston, F. Words their way with struggling readers. Pearson/Allyn & Bacon; Boston: 2011.

Frost R. Towards a universal model of reading. Behavioral and Brain Sciences. 2012; 35:263–329. DOI:10.1017/S0140525X11001841. [PubMed: 22929057]

Frost R, Grainger J, Carreiras M. Advances in morphological processing: An introduction. Language and Cognitive Processes. 2008; 23:933–941. DOI:10.1080/01690960802321925.

Gilbert JK, Goodwin AP, Compton DL, Kearns DM. Multisyllabic word reading as a moderator of morphological awareness and reading comprehension. Journal of Learning Disabilities. 2014; 47(1):34–43. DOI:10.1177/0022219413509966. [PubMed: 24219914]

Goodwin, A. 60th Yearbook of the Literacy Research Association. 2011. Does meaning matter for reading achievement? Untangling the role of phonological recoding and MA in predicting reading and vocabulary achievement for Spanish-speaking English language learners; p. 77-94.

Goodwin AP, Gilbert JK, Cho SJ. Morphological contributions to adolescent word reading: An item response approach. Reading Research Quarterly. 2013; 48(1):39–60. DOI:10.1002/rrq.037.

Goodwin AP, Gilbert JK, Cho SJ, Kearns DM. Probing lexical representations: Simultaneous modeling of word and person contributions to multidimensional lexical representations. Journal of Educational Psychology. 2014; 106(2):448–468. DOI:10.1037/a0034754.

Goodwin AP, Perkins J. Word detectives: Morphological instruction that supports academic language. The Reading Teacher. 2015; 68(7):504–517. DOI:10.1002/trtr.1342.

Harris, A. Greek morphemes lessons (It's not greek to me!). 2nd edn. GOTAGS; Nashville, TN: 2009.

Jiménez RT, García GE, Pearson PD. The reading strategies of bilingual Latina/o students who are successful English readers: Opportunities and obstacles. Reading Research Quarterly. 1996; 31:90–112.

Kieffer MJ, Lesaux NK. Knowledge of words, knowledge about words: Dimensions of vocabulary in first and second language learners in sixth grade. Reading and Writing: An Interdisciplinary Journal. 2012; 25:347–373. DOI:10.1007/s11145-010-9272-9.

Kuo LJ, Anderson RC. Morphological awareness and learning to read: A cross-language perspective. Educational Psychologist. 2006; 41:161–180. DOI:10.1207/s15326985ep4103_3.

Laxon V, Rickard M, Coltheart V. Children read affixed words and non-words. British Journal of Psychology. 1992; 83(3):407–423.

MacGinitie, W., MacGinitie, R., Maria, K., Dreyer, LG. Gates-MacGinitie reading test. 4th edn. Riverside Publishing Company; Itasca, IL: 2000.

Mahony DL. Using sensitivity to word structure to explain variance in high school and college level reading ability. Reading and Writing: An Interdisciplinary Journal. 1994; 6:19–44.

McCutchen D, Logan B, Biangardi-Orpe U. Making meaning: Children's sensitivity to morphological information during word reading. Reading Research Quarterly. 2009; 44:360–376. DOI:10.1598/RRQ.44.4.4.

Muse, AE. The nature of morphological knowledge (Doctoral dissertation). 2005. Retrieved from Proquest (No. 3198241)

Muthén, Muthén. Mplus (Version 7.2) [Computer software]. Muthén & Muthén; Los Angeles, CA: 2013.

Nagy W, Anderson R. The number of words in printed school English. Reading Research Quarterly. 1984; 19:304–330.

Nagy W, Berninger V, Abbott R. Contributions of morphology beyond phonology to literacy outcomes of upper elementary and middle school students. Journal of Educational Psychology. 2006; 98(1): 134–147. DOI:10.1037/0022-0663.98.1.134.

Nagy W, Berninger V, Abbot R, Vaughan K, Vermeulen K. Relationship of morphology and other language skills to literacy skills in at-risk second-grade readers and at-risk fourth-grade writers. Journal of Educational Psychology. 2003; 95(4):730–742. DOI:10.1037/0022-0663.95.4.730.

Nagy W, Carlisle JF, Goodwin AP. Morphological knowledge and literacy acquisition. Journal of Learning Disabilities. 2014; 47(1):3–12. DOI:10.1177/0022219413509967. [PubMed: 24219917]

Nagy WE, Townsend D. Words as tools: Learning academic vocabulary as language acquisition. Reading Research Quarterly. 2012; 47(1):91–108. DOI:10.1002/RRQ.011.

Nunes T, Bryant P, Bindman M. The effects of learning to spell on children's awareness of morphology. Reading and Writing. 2006; 19:767–787. DOI:10.1007/s11145-006-9025-y.

Pacheco MB, Goodwin AP. Putting two and two together: Middle school students' morphological problem solving strategies for unknown words. Journal of Adolescent and Adult Literacy. 2013; 56(7):541–553. DOI:10.1002/JAAL.181.

Perfetti CA. Reading ability: Lexical quality to comprehension. Scientific Studies of Reading. 2007; 11:357–383. DOI:10.1080/10888430701530730.

Raftery AE. Bayesian model selection in social research. Sociological Methodology. 1995; 25:111–163.

Reise SP, Morizot J, Hays RD. The role of the bifactor model in resolving dimensionality issues in health outcomes measures. Quality of Life Research. 2007; 16:19–31. DOI:10.1007/s11136-007-9183-7. [PubMed: 17479357]

Reichle ED, Perfetti CA. Morphology in word identification: A word experience model that accounts for morpheme frequency effects. Scientific Studies of Reading. 2003; 7:219–237.

Sangster L, Deacon SH. Development in children's sensitivity to the role of derivations in spelling. Canadian Journal of Experimental Psychology. 2011; 65:133–139. DOI:10.1037/a0018569. [PubMed: 21244134]

Siegel LS. Morphological awareness skills of English language learners and children with dyslexia. Topics in Language Disorders. 2008; 28:15–27.

Singson M, Mahony D, Mann V. The relation between reading ability and morphological skills: Evidence from derivational suffixes. Reading and Writing: An Interdisciplinary Journal. 2000; 12(3-4):219–252.

TDOE Report Card. [8-28-11] Tennessee Department of Education Report Card. 2011. Retrieved from http://edu.reportcard.state.tn.us/pls/apex/f?p=200:1:4463180647001600

Tighe EL, Binder KS. An investigation of morphological awareness and processing in adults with low literacy. Applied psycholinguistics. 2015; 36(02):245–273. DOI:10.1017/S0142716413000222. [PubMed: 25926711]

Tighe EL, Schatschneider C. Exploring the dimensionality of morphological awareness and its relations to vocabulary knowledge in adult basic education students. Reading Research Quarterly. 2015 DOI:10.1002/rrq.102.

Tong X, Deacon SH, Cain K. Morphological and syntactic awareness in poor comprehenders: Another piece of the puzzle. Journal of Learning Disabilities. 2014; 47(1):22–33. DOI:10.1177/0022219413509971. [PubMed: 24306458]

Townsend, D., Bear, D., Templeton, S. Academic Vocabulary Spelling Inventory. In: Templeton, S.Johnston, D., Invernizzi, M., editors. Vocabulary their way. Prentice Hall; Upper Saddle River, NJ: 2009.

Tyler A, Nagy W. The acquisition of English derivational morphology. Journal of Memory and Language. 1989; 28:649–667.

Tyler A, Nagy WE. Use of derivational morphology during reading. Cognition. 1990; 36:17–34. [PubMed: 2383968]

Valtin, R. Awareness of features and functions of language. In: Downing, J., Valtin, R., editors. Language awareness and learning to read. Springer-Verlag; New York: 1984. p. 227-260.

Van Kleeck A. The emergence of linguistic awareness: A cognitive framework. Merrill-Palmer Quarterly. 1982; 28(2):237–265.

Wagner, R., Muse, A., Tannenbaum, K. Vocabulary acquisition: Implications for reading comprehension. The Guilford Press; New York: 2007.

Zeno, SM., Ivens, SH., Millard, RT., Duvvuri, R. The educator's word frequency guide. Touchstone Applied Science Associates, INC; 1995.

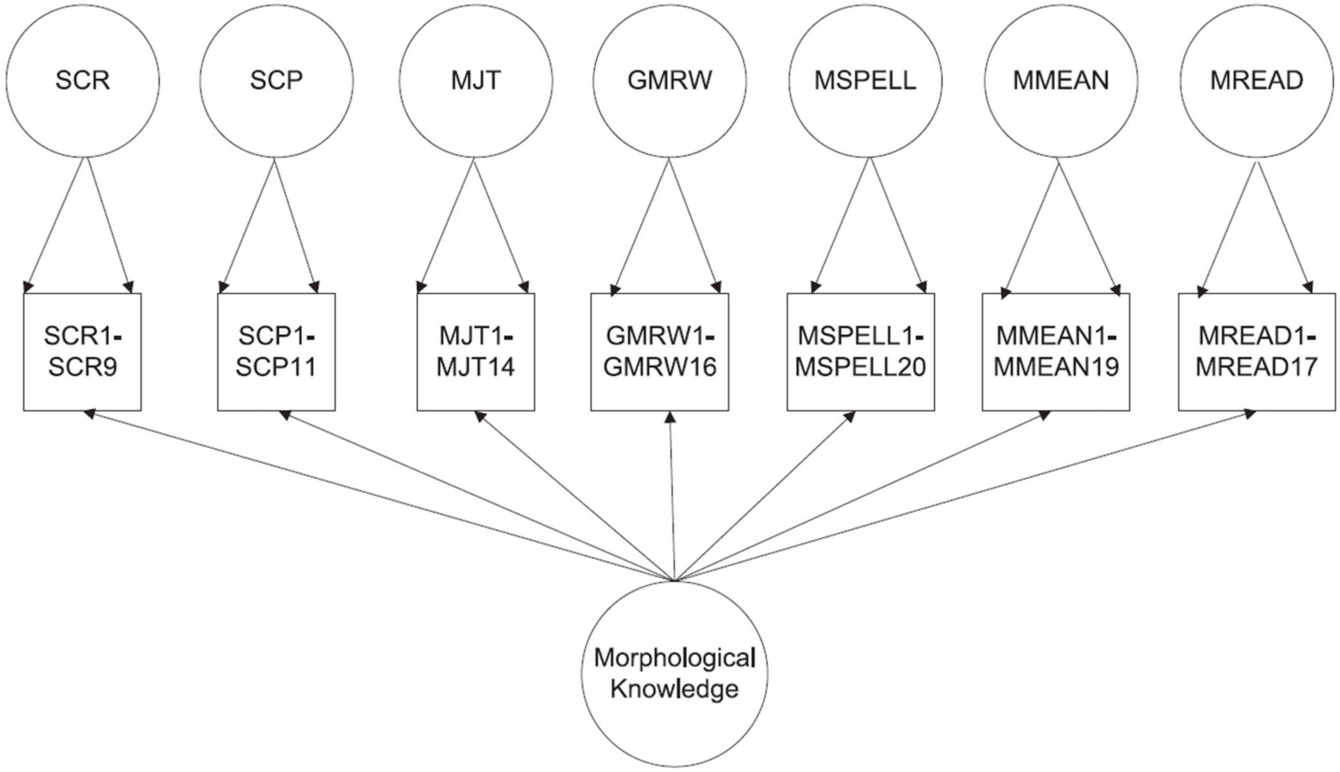



**Figure 1.**

Measurement model results showing multidimensionality of morphological knowledge. *Note.* Labels of observed variables are: *SCR* = suffix choice for real words; *SCP* = suffix choice for pseudowords; *MJT* = morphological judgement task; *GMRW* = Generate morphologically-related words; *MSPELL* = Morphological spelling processing; *MMEAN* = Morphological meaning processing; *MREAD* = Morphological word reading processing. See Appendix B for factor loadings for each item.

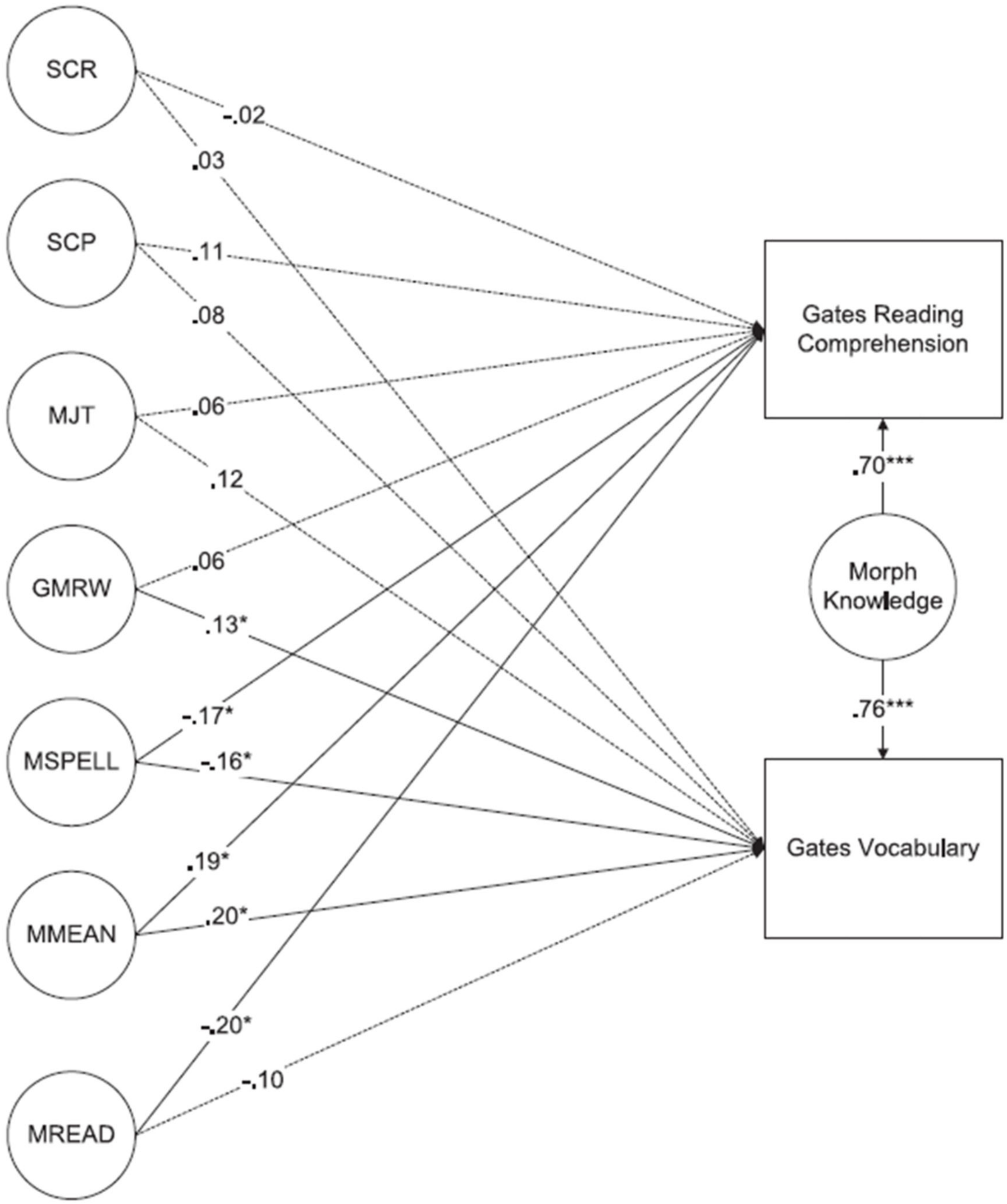


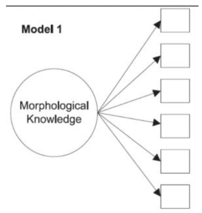
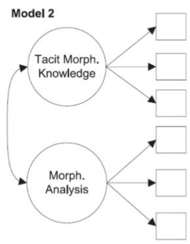
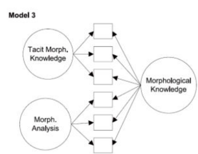

**Figure 2.**
Structural model results showing standardised coefficients of the general factor (i.e., morphological knowledge) and the seven specific morphological factors predicting reading comprehension and vocabulary.

*Note. SCR* = suffix choice for real words; *SCP* = suffix choice for pseudowords; *MJT* = morphological judgement task; *GMRW* = Generate morphologically-related words; *MSPELL* = Morphological spelling processing; *MMEAN* = Morphological meaning processing; *MREAD* = Morphological word reading processing; $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.


Author Manuscript
Author Manuscript
Author Manuscript

## Table 1

Alternative views of morphological knowledge dimensionality.

| View | Description | Example models |
|---|---|---|
| Unidimensional | Performance on different morphological knowledge tasks represents core elements of morphological knowledge; these are entirely explained by one general level of morphological knowledge. |  |
| Multidimensional | Performance on different morphological knowledge tasks represents different dimensions of morphological knowledge; these are distinctly explained by multiple correlated constructs (e.g., morphological processing and morphological analysis). |  |
| Bifactor | Performance on different morphological tasks represents both and overarching knowledge of morphology and distinct dimensions that are not subsumed by this general knowledge. |  |

*Note:* Morph = morphological.

**Table 2**

Experimental measures.

| # | Task type (morph. _) | Subtest | Adapted from | Skill assessed | Example item | # items (/) | Reliability α (/) | *N* | *Mean*/ *(SD)*/ | Min/, Max/ | Scale |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Analysis | Suffix choice real word (SCR) | Mahony (1994) | Complete sentence with best of four answers that are derivations with same stem. | Did you hear (*directs*, *directions, directed*)? | 25 (9) | .90 (.90) | 366 | 8.41 (1.64) | 0,9 | 0,1 |
| 2 | Analysis | Suffix choice pseudoword (SCP) | Singson et al. (2002) | Choose the most appropriate pseudoword to complete the given sentence. | Our teacher taught us how to (*jittling*, *jittles*, *jittle*). | 20 (11) | .85 (.82) | 366 | 9.20 (2.38) | 1,11 | 0,1 |
| 3 | Analysis | Morph. judgmental task (MJT) | Mahony (1994) | Determine whether pairs of words were morphologically related. | Does *personal* come from *person*? [*poet-poetic*, *add-addition*, *ill-illegal*]? | 24 (14) | .57 (.68) | 366 | 12.19 (1.99) | 3,14 | 0,1 |
| 4 | Analysis | Generate morph-related words (GMRW) | Townsend,Bear, &Templeton (2009) | Produce morphologically related words given a root word. | Given *forget*, produce related words [*forgetful*, *forgets*, *forgetting*]. | 40 (16) | .93 (.90) | 192 | 12.28 (4.06) | 0,16 | 0,1 |
| 5 | Processing | Morph. spelling (MSPELL) | Carlisle (1988) | Spell a dictated derived word correctly when related root was spelled correctly | Spell *finance*; Spell *financial*. | 40 (20) | .90 (.88) | 191 | 9.64 (5.07) | 0,20 | 0,1 |
| 6 | Processing | Morph. meaning (MMEAN) | Tyler and Nagy (1989) | Judge level of knowledge of a derived word's meaning based on level of knowledge of a related root word | Do you have *no*, *some*, *or full* knowledge of *finance's* definition? | 40 (19) | .88 (.87) | 190 | 9.95 (4.61) | 0,19 | 0,1 |
| 7 | Processing | Morph. word reading (MREAD) | Carlisle and Stone (2005) | Orally pronounce the written derived word correctly when the related root word is pronounced correctly | Read aloud *finance*; Read aloud *financial*. | 40 (17) | .89 (.83) | 311 | 10.32 (3.88) | 0,17 | 0,1 |

*Note:* Morph = morphological; morph-related = morphologically related; / = Information for culled item set.

## Table 3

Pearson product–moment correlations between experimental morphology and standardised outcome measures.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. SPR | 1.00 | .67 | .38 | .26 | .29 | .18 | .33 | .38 | .34 |
| 2. SCP | .75 | 1.00 | .51 | .41 | .55 | .25 | .50 | .50 | .48 |
| 3. MJT | .46 | .48 | 1.00 | .41 | .51 | .35 | .44 | .51 | .56 |
| 4. GMRW | .44 | .43 | .41 | 1.00 | .54 | .39 | .51 | .42 | .46 |
| 5. MSPELL | .47 | .56 | .49 | .62 | 1.00 | .55 | .59 | .55 | .54 |
| 6. MMEAN | .24 | .26 | .36 | .48 | .57 | 1.00 | .45 | .51 | .53 |
| 7. MREAD | .52 | .58 | .44 | .56 | .71 | .43 | 1.00 | .44 | .52 |
| 8. Gates RComp ESS | .51 | .50 | .52 | .49 | .58 | .49 | .47 | 1.00 | .70 |
| 9. Gates RVocab ESS | .48 | .48 | .56 | .53 | .55 | .51 | .55 | .70 | 1.00 |

*Note:* SCR = suffix choice for real words; SCP = suffix choice for pseudowords; MJT = morphological judgement task; GMRW= generate morphologically related words; MSPELL = morphological spelling processing; MMEAN = morphological meaning processing; MREAD = morphological word reading processing; RComp = reading comprehension; ESS = extended scale scores; RVocab = reading vocabulary; *p>.05. Upper diagonal are correlations for the reduced subscales; lower diagonal are correlations for original subscales.

## Table 4

Measurement model fit indices.

| Model | Description | $\chi^2$ | *df* | CFI | TLI | RMSEA | LB | UB | AIC | ABIC |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | One-factor (UNIDIMENSIONAL) | 6270.66 | 5459 | 0.89 | 0.89 | 0.020 | 0.017 | 0.022 | 22696.51 | 22854.14 |
| 2 | Two-factor (TACIT&STRATEGIC) | 6024.06 | 5458 | 0.93 | 0.92 | 0.017 | 0.014 | 0.019 | 22326.61 | 22484.98 |
| 3 | *Seven-factor (TASK)* | *5593.38* | *5438* | *0.98* | *0.98* | *0.009* | *0.000* | *0.013* | *21598.22* | *21771.46* |
| 4 | Second-order seven-factor (second order, TASK) | 5707.48 | 5452 | 0.97 | 0.97 | 0.011 | 0.006 | 0.015 | 22845.12 | 22953.24 |
| 5 | Two-factor bifactor (bifactor TACIT&STRATEGIC) | 5572.83 | 5353 | 0.97 | 0.97 | 0.011 | 0.005 | 0.014 | 21856.28 | 22312.29 |
| 6 | *Seven-factor* bifactor (bifactor *TASK*) | *5575.02* | *5353* | *0.97* | *0.97* | *0.011* | *0.005* | *0.014* | *21748.85* | *21985.29* |

*Note:* CFI = comparative fit index; TLI = Tucker–Lewis index; RMSEA = root mean square error of approximation, LB = RMSEA 95% confidence interval lower bound; UB = RMSEA 95% confidence interval upper bound; AIC = Akaike’s Information Criteria, ABIC = Sample Size Adjusted Bayes Information Criteria; the two best fitting models are italicised.

**Table 5**

Factor correlation matrix—seven-factor model.

| Construct | GMRW | MJT | SCP | SCR | MREAD | MSPELL |
|---|---|---|---|---|---|---|
| GMRW | 1.00 | | | | | |
| MJT | .55 | 1.00 | | | | |
| SCP | .48 | .82 | 1.00 | | | |
| SCR | .27 | .71 | .93 | 1.00 | | |
| MREAD | .65 | .65 | .64 | .52 | 1.00 | |
| MSPELL | .71 | .73 | .73 | .47 | .84 | 1.00 |
| MMEAN | .51 | .61 | .45 | .24 | .62 | .61 |