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Abstract

Purpose: Spelling is a skill that relies on an individual's linguistic awareness, the ability to overtly manipulate language. The ability to accurately spell is important for academic and career success into adulthood. The spelling skills of adults have received some attention in the literature, but there is limited information regarding which approach for analyzing adults' spelling is optimal for guiding instruction or intervention for those who struggle. Thus, we aimed to examine the concurrent validity of four different scoring methods for measuring adults' spellings (a dichotomous scoring method and three continuous methods) and to determine whether adults' linguistic awareness skills differentially predict spelling outcomes based on the scoring method employed.

Method: Sixty undergraduate college students who were determined to be average readers as measured by a word reading and contextual word reading task, were administered a spelling task as well as morphological, orthographic, phonemic, and syntactic awareness tasks.

Results: All four scoring methods were highly correlated suggesting high concurrent validity among the measures. Two linguistic awareness skills, morphological awareness and syntactic awareness, predicted spelling performance on both the dichotomous and continuous scoring methods. Contrastively, phonemic awareness and orthographic awareness predicted spelling performance only when spelling was scored using a continuous measure error analysis.

Conclusions: The results of this study confirm that multiple linguistic awareness skills are important for spelling in adults who are average readers. The results also highlight the need for using continuous measures of spelling when planning intervention or instruction, particularly in the areas of orthographic and phonemic awareness.

Keywords: spelling, adults, linguistic awareness

Spelling is a language-based skill that is important for success throughout the school years and later in life. Individuals who have a large repertoire of words that they can spell automatically from memory retain more cognitive resources to devote to the content of the message they are composing, leading to more complex and mature compositions (Berninger & Winn, 2006; Carlisle, 1995). Importantly, raters assign lower scores to written compositions that contain spelling errors than those that do not, even when the content is identical and they are not instructed to consider spelling during grading (Choi & Cho, 2018; Marshall & Powers, 1969). Further, poor spelling skills may limit job opportunities and the potential for career advancement. Indeed, 80% of job applications are negatively impacted by spelling errors (College Board, National Commission on Writing for America's Families, Schools, and Colleges, 2005).

Despite the importance of spelling for academic and career success, there is limited consensus in the literature regarding the optimal approach for scoring spelling performance (e.g., Clemens, Oslund, Simmons, & Simmons, 2014; Treiman, Kessler, Pollo, Byrne, & Olson, 2016). Traditionally, spelling has been scored dichotomously, as either correct or incorrect. However, some experts advocate for the use of spelling error analyses as a method for identifying areas of strength and weakness for educational planning among children and adults (e.g., Al Otaiba & Hosp, 2010; Bahr, Silliman, Berninger, & Dow, 2012; Masterson & Apel, 2010ab). Although spelling error analyses appear to have little advantage over dichotomous scoring for the purposes of predicting concurrent and future spelling performance (e.g., Treiman, Kessler, & Caravolas, 2019), whether these methods yield important information regarding an individual's linguistic skills has not been directly investigated. Thus, the purpose of the present study was to address this gap in the literature by evaluating the concurrent criterion validity of four approaches to scoring spelling among adult college students. Results are intended to assist educators in maximizing information obtained from spelling error analyses and to guide educators in selecting instructional foci. In the following literature review, we provide an overview of the research conducted on the spelling skills of adults, describe the evidence supporting the relations between linguistic awareness skills and spelling, and explain the approaches to scoring performance addressed in the present research.

Adult Spelling Skills

Researchers have devoted substantial resources to the investigation of spelling skills in adults (e.g., Burt & Fury, 2000; Coleman, Gregg, McLain, & Bellair, 2009; Foster, 1911; Greenberg, Ehri, & Perin, 2002). Findings from this body of work, which covers multiple languages including English and Dutch, indicate that college-level students and adults often make spelling errors in their writing (Burt & Fury, 2000; Foster; 1911; Herbots, 2005), and that language abilities are related to spelling in adults (e.g., Ocal & Ehri, 2017a). Vanderswalmen, Vrijders, and Desoete (2010) examined the spelling of over 2,000 Dutch-speaking college students and found that students made spelling errors on an average of 11% of words within their written compositions. Further, 27% of students made at least one error in their spellings of dictated sentences. Coleman and colleagues found that, in a sample of 65 typically-achieving, English-speaking undergraduate college students, 76% of participants made at least one spelling error when writing connected text in an essay (2009). Overall, the literature indicates that a relatively large percentage of college-age students have difficulty with spelling.

Through spelling error analyses, researchers also have found that there are differences in the frequency and types of spelling errors made by adults who have below-average literacy skills compared to individuals with typical literacy skills (e.g., Kemp, Parrila, & Kirby, 2008; Lefly &

Pennington, 1991). For example, via a spelling error analysis, Worthy & Vise (1996) found that adults with poor spelling skills had particular difficulty with the spellings of suffixes (e.g., -*t/ion*), but not basic orthographic pattern rules that govern the spelling of short vowels and consonants. It is not the case, however, that adults who are poor spellers are unable to make gains in spelling skills. Ocal and Ehri (2017b) reported that explicit training in orthographic mapping of spellings was as effective for college students who were poor spellers as it was for those who were good spellers.

Relations Between Spelling and Linguistic Awareness

Results from studies investigating both children and adults' literacy and literacy-related skills indicate that individuals' linguistic awareness skills are associated with their overall literacy achievement including spelling (e.g., Apel, Wilson-Fowler, Brimo, & Perrin, 2012; Berninger, Abbott, Nagy, & Carlisle, 2010; Fracasso, Bangs, & Binder, 2016; Kim, Apel, & Al Otaiba, 2013; Law, Wouters, & Ghesquière, 2015; Talwar, Cote, & Binder, 2014; Werfel, Schuele, & Reed, 2019; Wilson-Fowler & Apel, 2015). Individuals who are strong spellers have been shown to have not only higher overall literacy achievement, but also superior linguistic awareness skills compared to those who struggle to spell (Apel et al.,2012; Berninger et al., 2010; Kim et al.,2013; Werfel et al.,2019; Wilson-Fowler & Apel, 2015). Linguistic awareness refers to the ability to consciously think about and manipulate language and is a core component of reading and writing development. Because spelling requires the use of linguistic awareness abilities to accurately spell, individuals' spelling errors may provide insight into their underlying linguistic awareness skills (Apel & Lawrence, 2011; Fracasso, Bangs, & Binder, 2016; Guo, Roehrig, & Williams, 2011; McNeill & Everatt, 2013; Talwar, Cote, & Binder, 2014; Werfel & Krimm, 2015). The problem, however, is that in studies investigating the relation between spelling and linguistic awareness, most investigations have used a dichotomous scoring approach rather than analyzing individual spelling errors such as in Worthy and Vise (1996). Further, when spelling errors are analyzed (mostly in the child literature), researchers have adopted a variety of different approaches for classifying errors, making it difficult to determine which is the best for gaining insight into an individual's linguistic awareness skills.

There are four linguistic awareness skills that have received substantial attention in the literature as being associated with literacy development. These include morphological awareness, orthographic awareness, phonological awareness, and syntactic awareness. Morphological awareness denotes an individual's ability to consciously identify, manipulate, and reflect on morphemes, the smallest unit of meaning in language (e.g., Carlisle, 1995). Orthographic awareness involves the ability to consciously attend to how spoken language is represented in print, either knowledge of specific spellings of words, or the patterns and rules that generally guide word spellings (e.g., Apel, 2011; Ouellette & Sénéchal, 2008). Phonological awareness refers to an individual's ability to consciously think about and manipulate the sounds in a language (e.g., Nesdale, Herriman, & Tunmer, 1984); the term phonemic awareness applies when the level of analysis is at individual phonemes. Finally, syntactic awareness refers to an individual's ability to manipulate and reflect on a language's grammatical structures (e.g., Cain, 2007; Zipke, Ehri, & Cairns, 2009).

Two studies have examined adults' morphological awareness skills and their relation to their literacy abilities. Fracasso and colleagues (2016) examined the morphological awareness skills and spelling performance of students in an Adult Basic Education (ABE) program. The students completed tasks requiring them to complete a sentence with a derived form of a base word (e.g., farm. Bill is a _____), create a base form of a derived word to complete a sentence (e.g., Farmer. Bill lives on a ____) and choose one of four nonsense words with real suffixes to complete a sentence (e.g., Our teacher taught us the process of ___: “jittling” “jittled” “jittles” “jittle”). Fracasso and colleagues found that morphological awareness explained additional unique variance (5%) in spelling above that contributed by phonological decoding. Wilson-Fowler and Apel (2015) also examined the morphological awareness skills of 214 college students. Tasks used were similar to those by Fracasso and colleagues. Path analysis results suggested that morphological awareness was a significant and positive predictor of spelling (Wilson-Fowler & Apel, 2015).

Other researchers have investigated the relations between orthographic awareness, phonemic awareness, and adult literacy (e.g., Law et al., 2015; Talwar et al., 2014). In a study conducted by Talwar and colleagues (2014), sixty adult students from an ABE center completed spelling, real and pseudoword reading, morphological awareness, orthographic awareness, and phonemic awareness measures. The orthographic awareness task required participants to view a pair of words that contained either doubled consonants (bb or jj) or doubled vowels (aa or ee) and determine which word of the pair looked more like a real word. The phonemic awareness measure included two components: (a) discrimination of whether initial phonemes of two orally presented words were the same, and (b) deletion of sounds from words. A pseudoword reading task was combined with the phonological awareness tasks to make up a composite phonological awareness measure. Given that pseudoword reading requires knowledge of orthography, this task may have been better described as assessing the students’ orthographic knowledge, rather than solely their phonological awareness (Apel, Henbest, & Masterson, 2019). Finally, the morphological awareness measure combined the same three tasks used by Fracasso and colleagues (2016). Performance on the orthographic awareness task was not significantly related to spelling performance. The phonemic awareness composite score and real word reading together accounted for 52% of the variance in spelling, but morphological awareness did not uniquely predict spelling.

In a study focused on university students, Law and colleagues (2015) administered measures of word-level reading, reading comprehension, spelling, vocabulary, morphological awareness , and phonemic awareness to 36 students with dyslexia and 54 students without a diagnosis of dyslexia. The morphological awareness measures were similar to the tasks used by Fracasso and colleagues (2016). The phonemic awareness measure included tasks (later combined) requiring the students to replace sounds within words with other sounds, delete sounds, and transpose first sounds between pairs of words. Law and colleagues found that, for students with dyslexia, phonemic awareness did not explain any significant variance in spelling performance when entered first into a hierarchical regression analysis. Contrastively, phonemic awareness accounted for 26% of the variance in spelling performance for students without dyslexia. Both for students with and without dyslexia, morphological awareness was significantly related to spelling performance (17% and 19%, respectively) after controlling for phonemic awareness and vocabulary.

To our knowledge, only one study to date has analyzed the relation between college students' spelling performance and syntactic awareness. Kemp and colleagues (2009) administered a measure of syntactic awareness and a spelling dictation task to 67 college student participants. The syntactic awareness task required the students to make verb tense changes to a word in a sentence via analogical reasoning from previously read sentences. The relation between the students' syntactic awareness and spelling performance was moderate and significant (r = .62). It should be noted that, given the students were required to consider verb tense changes, which also involves morphological awareness (i.e., an awareness of how inflectional morphemes affect the sound and spelling of verbs), the task may have been best described as a morpho-syntactic awareness measure.

Overall, findings suggest that there are four linguistic awareness skills that may contribute to adult spelling performance. For the most part, morphological awareness has consistently been shown to predict adults' spelling performance above and beyond other measures of language and linguistic awareness (e.g., Fracasso et al., 2016; Law et al., 2015), but see Talwar and colleagues (2014) for an exception. Second, orthographic awareness, despite receiving limited attention in the adult literature (e.g., Talwar et al., 2014), has been shown to be an important predictor of spelling development among children from a range of ages and backgrounds (e.g., McNeill & Everatt, 2013; Roman, Kirby, Parilla, Wade-Woolley, & Deacon, 2009; Shahar-Yames & Share, 2008; Tucker, Castles, Laroche, & Deacon, 2016) and warrants further consideration in relation to adult spelling skills. Third, there is evidence that phonemic awareness positively relates to spelling performance in adults (e.g., Law et al., 2015; Talwar et al., 2014). Finally, syntactic awareness, despite receiving limited attention in the literature, appears to relate moderately to spelling performance. Consequently, there is evidence supporting the inclusion of measures of all four of these linguistic awareness skills in evaluating the concurrent-criterion validity of approaches to scoring spelling performance. The manner in which researchers have scored adults' spelling attempts, however, have differed.

Approaches for Scoring Spelling Performance

The most common approaches to scoring individuals' spelling performance can be described as belonging to one of two categories: dichotomous or continuous. The dichotomous approach to scoring spelling is straightforward; individuals are awarded a single point for a correctly spelled word and zero points for an incorrect spelling. A continuous approach assigns scores based on the linguistic properties that are present in the spelling and provides a score based on a scale. The dichotomous approach has the advantage of being simple to implement and requiring little time. Additionally, the dichotomous approach has been shown to predict spelling development at least as well as more continuous scoring approaches among children in the early elementary grades (Treiman, Kessler, Louis, Byrne, & Olson, 2016). However, a key weakness of the dichotomous scoring approach is that it does little to guide educational planning for individuals in need of supplementary spelling instruction.

The premise for some continuous scoring systems is that they more precisely quantify the linguistic quality of spellings; therefore, they may provide more precise insight into linguistic awareness skills (Al Otaiba & Hosp, 2010; Coleman et al.2009; Masterson & Apel, 2010ab; Morris, 1980). For example, a word that is spelled in a way in which each phoneme in the word is represented by a letter or letters is qualitatively different from a word that is spelled in a way that fails to represent a phoneme or phonemes (e.g., Masterson & Apel, 2010ab). Likewise, a spelling error that consists of a letter or letters that is a plausible or legal spelling of a sound (e.g., ‘k’ or ‘c’ for /k/) demonstrates more sophisticated orthographic knowledge than a spelling that is not phonologically plausible (‘p’ for /k/; e.g., Apel & Masterson, 2010ab; Fischer et al., 1985; Greenberg et al., 2002). Continuous scoring systems may be useful for monitoring progress with spelling improvement (e.g., Bailey, Arciuli, & Stancliffe, 2017; Masterson & Apel, 2010b). In fact, Bailey and colleagues (2017) found that, following intervention, improvements in children’s spelling scores were evident based on a continuous scoring system, but not on a dichotomous system.

Researchers have adopted various continuous methods for analyzing spelling errors in children and adults (e.g., Bahr et al., 2012; Bebout, 1985; Bowers, McCarthy, Schwarz, Dostal, & Wolbers,2014; Clemens et al.,2014; Fischer et al., 1985; Greenberg et al., 2002; Masterson & Apel, 2010ab). The three methods of interest within the present paper are the Spelling Sensitivity System (SSS)-Element Score, the SSS-Word Score, and the Levenshtein Distance. The first two can be calculated using the *Computerized Spelling Sensitivity System* (*CSSS*; Masterson & Apel, 2010b; Masterson & Hrbec, 2011) and have been used in several papers to provide a continuous score for spelled words (Apel & Lawrence, 2011; Apel & Masterson, 2015; Bailey et al., 2017; Clemens et al., 2014; Masterson & Apel, 2010ab; Masterson & Apel, 2013; Werfel & Krimm, 2015). The *CSSS* provides detailed guidelines for parsing spelling words into elements by phonemes and, when the word contains affixes, by morphemes. Spellings are then scored at the element level based on the correctness of that element. If an element is spelled correctly, it receives a score of three. If an element is spelled incorrectly but with a spelling that follows spelling conventions in English, it receives a score of two. For example, in the case of grotesk/grotesque, the 'k' grapheme is a legal spelling for the /k/ sound; this grapheme just does not appear in this word. An incorrectly-spelled element with a spelling pattern violation in English receives a score of one. For example, in the case of grotesp/grotesque, the 'p' grapheme can never represent the /k/ phoneme; it is not a legal substitution. If the element is entirely omitted, it receives a score of zero. For example, in the case of grotes/grotesque, the /k/ sound was not represented by a letter(s). After determining scores for each element, the Element Score and Word Score (continuous measures) can be calculated. For the Element Score, each word receives a total score by averaging the scores awarded for each element. For the Word Score, each word receives a total score based on the lowest number of points assigned to any element included in that word. For example, if a word including three elements was assigned scores of 3, 2, and 0, then the Element Score would be 1.67 (average of element scores), and the Word Score would be 0 (lowest element score).

The Levenshtein distance (1965) provides a calculation for the distance between two symbols and was used in a previous investigation by Treiman and colleagues (2019). As in Treiman and colleagues' paper, we used Levenshtein distance to determine letter distance, that is, the difference between the letters in the target spelling word and the letters in the individuals' spellings. Specifically, spellings were penalized for letter omissions, substitutions, or additions. For example, a spelling of 'neccesitate' for 'necessitate' would earn two penalties, one for the additional 'c' and one for the deletion of the 's'.

Present Study

To date, most researchers have investigated the relation between linguistic awareness skills and spelling performance using a dichotomous approach. The present study adds to this literature by investigating the relation between linguistic awareness skills and continuous approaches to scoring spellings of college-age adults. Specifically, we assessed the concurrent criterion validity of dichotomous plus three continuous scoring approaches relative to measures of linguistic awareness developed for college-age adults. In addition to a dichotomous correct-incorrect whole word scoring approach, the adults' spellings were scored based on types of errors (phonological, orthographic) on the words' constituent elements (phonemes, morphemes) as well as a measure of letter distance (Levenshtein, 1965). To evaluate the relative value of each of these approaches in determining the contribution of each linguistic awareness skill to spelling performance, the following research questions were addressed:

1. How does a dichotomous approach to measuring adults' word-level spelling relate to the continuous approaches to evaluating spelling?
2. Does morphological, orthographic, phonemic, and syntactic awareness predict adults' spelling differentially in dichotomous compared to continuous scoring approaches?
3. What is the concurrent criterion validity of dichotomous compared to continuous scoring approaches?

Method

Participants

A total of 60 undergraduate college students between the ages of 18 and 38 participated in this investigation (*M* = 21.03, *SD* = 2.65). The students were recruited from a university in a southeastern region of the United States. Fifty (83%) of the students were enrolled in an introductory course in speech-language pathology and audiology and were offered extra credit for participation. Of the students from the introductory course, 47 (94%) were public health or other health professions majors (e.g., nursing). Three (6%) of the students from the introductory course were declared majors unrelated to the health professions. The final 10 (17%) of the 60 participants were recruited via flyers placed throughout the university campus; their majors were not reported. To our knowledge, with the exception of one participant who had a minor in communication sciences and disorders, none of the participants had taken a course that may have strengthened one or more of their linguistic awareness skills (e.g., a phonetics or linguistics course) prior to participation in this study. Additional participant demographic information is provided in Table 1.

Seventy participants originally signed up to participate in the study, however, because linguistic awareness skills and spelling error analyses have received little attention in the adult literature, we specifically were interested in understanding their relations in a typical adult population. Therefore, only data from participants with average performance on at least one of the reading screeners and who reported no history of difficulty with reading were included in analyses. For the reading screeners, participants were included based on two criteria: (a) achieving a standard score between 85 and 115 on one of the two reading measures (see descriptions below); and (b) scoring no lower than 1.5 standard deviations below the normative mean on the other reading measure. Three participants self-reported a history of reading difficulties and were excluded from data analysis. A total of six participants did not meet eligibility criteria based on the reading screeners and one participant signed up to participate but then did not complete testing (total excluded from analyses = 10) Therefore, the final total sample size was 60.

Procedure

Upon receipt of signed consent forms, students were administered tasks to assess their morphological, orthographic, phonemic, and syntactic awareness, as well as their reading and spelling abilities. All students were administered the tasks in the same order and received the same instructions for all tasks. The students who were enrolled in the introductory course in speech-language pathology and audiology were administered the tasks in a classroom setting. Other students were tested in a small group or individually at the university's speech and hearing center. The reading and spelling tasks were completed first followed by the linguistic awareness measures. All assessments included written instructions to reduce demands on students' working memory. The students were told to complete the tasks on their own (i.e., without verbal instructions) and in the order of presentation. Students were instructed to not go back to previous tasks or items after starting administration. The assessments were designed to evaluate participants' morphological awareness, orthographic awareness, phonemic awareness, and syntactic awareness.

Measures

The *Test of Silent Word Reading Fluency-2nd Edition* (TOSWRF-2; Mather, Hammill, Allen, & Roberts, 2014) was utilized as a brief measure of students' printed word recognition skills. Unrelated words were presented in rows of text without spaces between them (e.g., birdupkickheryellowlike). Participants were instructed to draw vertical lines between the words to indicate word breaks. The task was timed, requiring participants to separate as many words as possible within three minutes. All instructions for this task were delivered in accordance with the test's manual. Test-retest reliability for the age range included in this study is reported to be .93 (Mather et al., 2014).

The *Test of Silent Contextual Reading Fluency-2nd Edition* (TOSCRF-2; Hammill, Wiederholt, & Allen, 2014) was administered to evaluate students' efficient recognition of printed words in a meaningful context. Similar to the TOSWRF-2, the tool includes words presented in rows of text without spaces (e.g., THEGIRLSATECAKEATTHEPARTY). The participants were again instructed to draw vertical lines between the words to indicate breaks within a three-minute time limit. Unlike the TOSWRF-2, however, the words in each trial of the TOSCRF-2 create a meaningful sentence. The sentences increase in syntactic and semantic complexity as the trials continue, requiring participants to draw on increasingly heightened levels of linguistic knowledge to complete the task efficiently. Test-retest reliability for the age range included in this study is reported to be .88 (Hammill et al., 2014).

Spelling. Participants completed an experimenter-developed spelling task in which they were instructed to spell 30 real words dictated by the examiner. The examiner said each word aloud in isolation, provided an example of the word being used in a sentence, and then said the word again in isolation. All words, with the exception of two, were multisyllabic. Three of the multi-syllabic words contained only one morpheme. Twenty of the 30 words were multimorphemic in that they were made up of a free base word and an affix or affixes (e.g., mis-, -ible, -ion). Five of the words were made up of a root and bound morpheme. The task was designed to draw upon not only phonological and orthographic knowledge, but also participants' mastery of written morphemes and their influence on spelling. Several words for which phonological, orthographic, and morphological knowledge could not explain the complete spelling of the word (e.g., silhouette) also were included. See complete spelling list in Appendix.

Four scores were derived from students' performance on the spelling task, following the protocols for the scoring approaches addressed in the literature review. First, students received scores based on the dichotomous approach to evaluating spelling. Students received one point for a correct response and zero points for a response including one or more errors (max score: 30). The second and third approaches, which both employed the *Computerized Spelling Sensitivity System* (CSSS; Masterson & Apel, 2010b; Masterson & Hrbec, 2011), were the Element Score and the Word Score. The final approach was the Levenshtein distance (Levenshtein, 1965), which was computed using the vwr package in R (Keuleers, 2013).

After each word was scored following previously described guidelines, total scores were computed on each measure for the participants. To do this, scores were averaged across all words for each participant (e.g., max score for Element Score or Word Score was 3). Cronbach's alpha was obtained to assess reliability of measurement within the present sample. For dichotomous scoring (i.e., correct vs. incorrect), $\alpha = .85$. For both the Element and Word Scores, $\alpha = .83$. For the Levenshtein distance, $\alpha = .86$. Therefore, internal consistency was satisfactory for each scoring method (Nunnaly, 1978).

Morphological awareness task. A derivational morphology task designed for college students was used to evaluate participants' morphological awareness skills (Wilson-Fowler & Apel, 2015). To complete the task, participants were required to identify the appropriate morphological derivation of a given word to fit within an incomplete sentence. For example, students were shown the printed sentence: "Impress: John wanted to make a good ________on his first date." Having been given the base word "impress," the students were told to "change the word that is given to fill in the blank in the sentence." The accepted correct response for this example was "impression."

The morphological awareness task contained 4 practice items followed by 16 test items. A complete list of the task items is available in Wilson-Fowler and Apel (2015). Of the test items, 5 required no orthographic or phonological shift to the base word (e.g., odd/oddity), 2 required a phonological shift (e.g., logic/logician), 3 required an orthographic shift (e.g., weary/weariness), and 6 required both an orthographic and phonological shift to the base word (e.g., muscle/muscular). The target words ranged from 2-4 syllables. Participants' responses were scored on a binary scale. As in other investigations (e.g., Goodwin, Petscher, Carlisle, & Mitchell, 2017; Kirk & Gillon, 2009), responses were scored as incorrect if the entire word was not spelled correctly because a) the base part of a multi-morphemic word is a morpheme and b) morphological awareness involves knowing the manner in which written affixes connect to base words including the modifications they make to base words' spellings. Cronbach's alpha for this task was .81 within the present participant sample.

Orthographic awareness task. To assess students' orthographic awareness, an orthographic choice task like those created by Olson, Forsberg, Wise, and Rack (1994) and Kim, Apel, and Al Otaiba (2013) was used. The task included a single practice item and 35 test items comprised of nonsense word pairs (e.g., *krumpador-chrumpador*; *noop-niip*). Nonsense word pairs were used to focus the assessment on general knowledge of orthographic patterns/conventions, rather than on knowledge of specific known words (Nation, Angells, & Castles, 2007). One of the nonsense words within each of the pairs violated a rule of English orthography. The other nonsense word in the pair did not include any English orthography rule violations. Participants were asked to circle the word that "most looks like a real word" based on English word spellings. They received one point for a correct response and zero points for an incorrect response.

The orthographic rule violations included in the task mirrored those used by Kim and colleagues (2013). Specifically, awareness of the following rules was assessed: (a) digraphs for the /ʧ/ phoneme (e.g., *litch – lich*), (b) marking the /rk/ and /kr/ blends (e.g., *krasp – crasp*), (c) consonant/vowel doubling (e.g., *akke* - *noop*), (d) vowel/consonant representations of the vocalized /l/ and /r/ phonemes (e.g., *tibl – tible; kr* - *ker*), (e) the vocalized /l/ phoneme after consonant doubles (e.g., *fottle – fottel*), (f) representation of the /ŋ/ when followed by a /k/ phoneme (e.g., *chank – changk*), (g) use of 'nce' for /ns/ depending on the preceding vowel (e.g., *ebmilanse* - *ebmilance*), (h) rules for representing /ntʃ/ and /mf/ (e.g., *brentch* - *brench*; *samph* - *samf*), (i) changing 'y' to 'i' when adding a suffix (e.g., *grollyed* - *grollied*), (j) doubling consonants when adding the 'ing' (*sheaping* - *sheapping*), and (k) adding 's' vs. 'es' for the plural (e.g., *duxes* - *duxs*). These patterns were chosen because they are considered later-developing patterns (Wasowicz, Apel, Masterson, & Whitney, 2012).

The test item nonsense words varied in their orthotactic probabilities. According to the MCWord database (Medler & Binder, 2005), the number of word forms that shared the same bigrams as the test items ranged from 233 to 4,497, with a mean of 3,000. Thus, although the words were pseudowords, all contained bigrams that were similar to real words.

Notably, although the orthographic patterns included in the present task were the same as those used by Kim and colleagues (2013), the task was modified to include more multisyllabic nonwords. This was to increase the complexity of the assessment and make it more appropriate for college-age participants. Because the exact subset of items included in the present orthographic awareness task had not been implemented in previous research, students' item-level performance was examined carefully for evidence of measurement unreliability. First, all analyses were conducted with the full set of 35 items. Then, a subset of 10 items were selected from the original items set based on the percent accuracy, item-total correlations, and improvement in internal consistency reliability following removal of that item. Items with low variability in percent accuracy (i.e., all participants responded correctly), negative item-total correlations, and whose removal would result in substantial increases in internal consistency were iteratively removed. The final subset of 10 items yielded a coefficient of .71 for Cronbach's alpha. Analyses were repeated with this subset of 10 items.

Phonemic awareness task. To assess participants' phonemic awareness skills, a phoneme identification task developed by Spencer, Schuele, Guillot, and Lee (2008) was used. For this task, students viewed a real word printed on paper and were instructed to identify the number of sounds present in that word (e.g., "How many sounds are in the word *cat*?"). Students responded by circling a number between one and ten next to the printed word. The participants received one point for a correct response and zero points for an incorrect response. The task included 21 total items, 16 of which included a 1-1 correspondence between graphemes/digraphs/trigraphs and phonemes (e.g., run, ball, thin). The five remaining items contained either a silent letter (knuckle), an e-conditioned spelling (e.g., use), or an affix (e.g., teacher). All but one of the items used were identical to those developed by Spencer and colleagues (2008). The exception was 'squirrel,' which was replaced with 'squeamish' because of variation noted in pronunciations of the word 'squirrel' (i.e., /skwɝəl/ versus /skwɝl/). Cronbach's alpha for the phonemic awareness measure was .88 within the participant sample.

Syntactic awareness task. A grammatical judgement task, previously implemented with high school students (Brimo, Apel, & Fountain, 2015), was used to assess participants' syntactic awareness. Students viewed 17 written sentences, 15 of which contained syntactic errors (e.g., "A ship carried a cargo of wheat sailed into the harbor"). For each sentence, the students were instructed to indicate whether the sentence was grammatically correct and then, for sentences judged to be grammatically incorrect, to rewrite the sentence correctly (e.g., "A ship that carried a cargo of wheat sailed into the harbor"). The participants were provided with two example sentences before the test items. Responses were then scored on a two-point scale, with one point awarded for correctly identifying whether the sentence was correct, and one point awarded for providing a grammatically-correct revision of originally incorrect sentences. Cronbach's alpha for this task was computed to be .73 for the present sample.

Scoring Reliability

Speech-language pathology graduate students trained by the authors scored all tasks completed by the participants. To evaluate student scorers' reliability, all tasks for 20% of the participants were re-scored by an independently trained graduate student who was blind to the original scores. Inter-rater reliability was calculated by computing the percent agreement at the item level for each task that was double-scored. Reliability ranged from 97% to 100%.

Analyses

All analyses were conducted in the R environment (R Core Team, 2018). Students' performance on all tasks was first examined through descriptive statistics and histograms. To address the first research question regarding the relations between each of the four approaches to measuring spelling, scatterplots were examined and bivariate correlations obtained using Pearson's *r*. Next, to evaluate the contributions of the linguistic awareness measures to the various spelling measures, four multiple regression models were run. Each model included the four linguistic awareness measures predicting one of the spelling outcome measures. All models were examined for evidence of parameter bias attributable to multicollinearity. To address the final research question, the adjusted R-square values for each of the measures of spelling were obtained within the multiple regression models. The R-square values allowed us to examine the proportion of variance in the spelling outcome measures that could be predicted by the linguistic awareness predictor variables. The residual variance indicates the proportion of variability in the spelling measures that was not able to be predicted by the included linguistic awareness skills. The residual therefore can be considered to be unexplainable or error variance within the current models.

To assess statistical significance in all modeling, a correction factor was applied to p-values to account for the inclusion of multiple predictors. The Benjamini–Hochberg linear step-up procedure was used (Benjamini & Hochberg, 1995). A false discovery rate of 5% was used to create the correction factor. Values below the critical value obtained from the procedure were considered significant and are denoted in the results.

Results

The descriptive results of students' performance on all the tasks are provided in Table 2. Participants' scores on the measures of word and contextual reading were relatively normally distributed within the average range. When scored dichotomously, students spelled an average of 14.27 of the 30 words correctly (*SD* = 5.67). When they did make spelling errors, they tended to spell at least one syllable correctly for each word. Using the continuous scoring, for all participants, 48% of the words were spelled correctly, 19% were legal, but incorrect, 27% contained an illegal spelling pattern, and 6% of the spellings were lacking representation of a phoneme or morpheme. The linguistic awareness measures provided results similar to trends observed in previous work (e.g., Guo, Roehrig, & Williams, 2011; Jarmulowicz, Hay, Taran, & Ethington, 2008; Tighe & Binder, 2015; Wilson-Fowler & Apel, 2015). Participating adults received a wide range of scores on the tasks, suggesting significant variability in the linguistic awareness skills assessed.

Relations between Dichotomous Scoring and Continuous Scoring

To address our first research question, the relation between the dichotomous approach to scoring spelling and continuous approaches were examined via scatterplots and Pearson's *r* correlations. Scatterplots and bivariate correlations (see Table 3) revealed strong, significant and positive correlations between each of the measures of spelling. The dichotomous approach to spelling scoring correlated at $r = .91$ with the Word Score, at $r = .96$ with the Element Score, and at $r = -.90$ with the Levenshtein Distance (higher scores indicate larger deviation from the target word). Scatterplots further revealed a linear relation between each of the spelling measures, lending support for the use of Pearson's *r* to describe the associations between the variables.

Spelling Performance and Linguistic Awareness

To address our second aim, linear modeling was employed to determine whether measures of linguistic awareness predicted adults' spelling differentially depending on whether spelling performance was scored dichotomously or continuously. Results are provided in Table 4. Students' morphological awareness performance was a stable and significant predictor of all four measures of spelling. Students who scored higher on the morphological awareness task consistently demonstrated higher spelling scores, regardless of scoring approach. Comparably, syntactic awareness significantly predicted spelling scores for the dichotomous, Element, and Word scoring approaches. Holding all other linguistic awareness measures constant, participants who scored higher on the syntactic awareness task scored higher on those measures.

The participants' performance on all 35 items of the original orthographic awareness measure did not predict spelling, regardless of scoring approach. The revised 10-item orthographic awareness measure, however, did significantly predict participants' spelling above and beyond the other linguistic awareness measures when spelling was measured continuously. These results suggest that the increased reliability obtained through revising the orthographic awareness scale likely improved the construct validity of the measure. Consequently, results are reported only for analyses conducted with the 10-item orthographic awareness measure.

Phonemic awareness similarly differed in its relation to spelling by measure type. It was positively associated with all four spelling measures. However, phonemic awareness did not meet criteria for significance predicting students' dichotomously scored spelling. It did meet significance criteria for predicting both students' Element and Word scores and the Levenshtein distance. This finding suggests that additional meaningful variance may have been captured by the continuous scoring that was not detected in the dichotomous approach to scoring.

Concurrent Criterion Validity of Spelling Scoring Approaches

To address our third aim, the R-square values obtained from each of the four-predictor regression models (see Table 4) were used to compare the concurrent criterion validity among the spelling approaches. The Element and Word Scores had the same proportion explainable variance (R^2 = 0.57), given the available predictors. The Levenshtein Distance yielded an R^2 of 0.56. Less variability in the dichotomous scoring approach could be explained by the linguistic awareness predictors (R^2 = 0.49). Restated, 57% of the variance in students' Element Scores could be predicted by morphological, orthographic, phonemic, and syntactic awareness. The remaining 43% of the variance was attributable to participant characteristics not included in the model and measurement error. Similar interpretation applies to the Word Score and the Levenshtein Distance. For the dichotomous scoring approach, 49% of the variance was explained by the four linguistic awareness measures. The remaining 51% was credited to outside participant characteristics and measurement error.

Discussion

In this investigation, we were interested in better understanding how the type of spelling error analysis approach impacted the measurement of college students' spelling skills and how different linguistic awareness skills accounted for variance on the different error analysis procedures. Given the importance of adequate spelling abilities for academic, social, and vocational outcomes, a solid understanding of how measurement affects spelling error analysis outcomes in college students is necessary, both for describing abilities as well as planning instructional content for students lacking adequate spelling skills.

Our first aim was to determine whether the types of error analysis used, either a dichotomous approach or continuous measures, were related to one another when used to assess college students' spelling skills. Our results suggest that, for students in the average range of abilities, dichotomous and continuous analysis procedures are highly associated with one another. Correlation coefficients were all high, though the correlations among the continuous approaches were stronger than those observed with the dichotomous approach. This finding may reflect differences in the sensitivity of these two scoring approaches. The continuous approaches theoretically provide the most precision in scoring and would be most related to one another. For example, for the Element Score, individuals are awarded points for each segment of each word, which are then averaged to produce the Element Score. Likewise, for the Levenshtein Distance, penalties are assigned based on the number of symbols (i.e., letters) written incorrectly based on the target word. The dichotomous approach theoretically offers the least precision, given that individuals are awarded either a zero or a one for each word. Based on the obtained correlations, the dichotomous approach and the Levenshtein Distance were the most disparate.

Our second aim addressed whether any of the four linguistic awareness skills measured (i.e., phonemic, orthographic, morphological, or syntactic awareness) predicted the college students' spelling skills using the different analysis procedures. Given any of the four scoring procedures, morphological awareness was a consistent and significant predictor of spelling. This finding may have occurred because 20 of the spelling words were multi-morphemic; these stimuli then may have increased the students' use of morphological awareness to spell the words. That is, if any of the words were not automatic in their spelling, students would have been required to think about the affixes required to spell the word correctly and whether they modified the spelling of the base word and/or juncture to add the suffix. Our findings of the significant variance explained in spelling ability by morphological awareness is consistent with past investigations of the effect of morphological awareness on spelling ability (e.g., Fracasso et al., 2016; Wilson-Fowler & Apel, 2015). This finding also is not surprising given that estimates suggest that over 50% of words in the English language are morphologically complex (Anglin, Miller, & Wakefield, 1993).

Interestingly, syntactic awareness was a significant predictor for both the dichotomous scoring method and two of the three continuous scoring methods. At first, this finding seems counterintuitive given spelling was measured using a dictated, word-level spelling measure. However, there are several reasonable explanations for this finding. First, it is possible that the correlation simply reflects a general underlying intelligence or ability. Individuals with stronger language skills in one area are likely to have strong language in another area (e.g., Arciuli, 2018). Further, it may be that our syntactic awareness task was a morphosyntactic measure. That is, to successfully complete the syntactic awareness task, the students needed to think explicitly about grammar as well as the inflectional and derivational aspects of words that help cue readers into grammatical class. Thus, the significant prediction of syntactic awareness on spelling may have been due to some aspect of morphological awareness that went beyond those morphological awareness skills tapped by the morphological awareness task we used. It may also be worth considering that the spelling task was administered by presenting the target words within a sentence. It is possible that this element of the administration led to syntactic awareness skills being used during the spelling task.

Orthographic awareness predicted spelling performance only when assessed using the continuous measures. This suggests that in contrast to the dichotomous-based scoring approach, the continuous analyses, were more sensitive to individual differences in the students' orthographic awareness skills. This finding is important because orthographic knowledge includes both the knowledge of general orthographic patterns as well as the knowledge of specific word spellings. A dichotomous scoring procedure only assesses the latter aspect of orthographic awareness. Continuous analyses allow the assessment of both aspects of orthographic knowledge, an important benefit should one be using spelling analyses to plan spelling instruction for college-aged adults.

In addition to orthographic awareness, phonemic awareness contributed to spelling differently depending on the analysis procedure used. Using the dichotomous scoring system, phonemic awareness did not provide unique variance to spelling. However, when using any of the three continuous systems, phonemic awareness did make unique and significant contributions to spelling. The procedures for scoring the continuous approached likely led to these findings. For both the Element and Word scores, difficulty with using phonemic awareness to spell words notably reduced the score on the target word. Thus, greater variation in scores may have led to stronger relations between phonemic awareness and spelling. Similarly, using Levenshtein distance, a penalty was assigned for a missing letter, which in some cases may have signaled a phonemic awareness issue (e.g., 'debutate' for 'debutante'. The overall finding that phonemic awareness contributes uniquely to spelling is in line with past reports of the variance explained by phonemic awareness on spelling in adults (e.g., Law et al., 2015; Talwar et al., 2014). Additionally, that phonemic awareness predicted continuous scores but not dichotomous scores, particularly in light of their high concurrent validity, indicates the need for continuous scores in determining instructional targets for adults. That is, dichotomous scores appear to be sufficient for categorizing adult spellers' abilities broadly, but continuous approaches are necessary to select appropriate linguistic instructional targets.

Results of our third aim revealed, overall, that there is a distinction between the dichotomous approach to scoring adult's word-level spelling compared to continuous scoring. The continuous approaches to assessing spelling captured additional meaningful variance in the participating adults' spelling ability that was not represented in the dichotomous scoring approach (roughly 56-57% vs. 49%). This finding is important both for our general understanding of spelling in adults as well as when considering assessment that is focused on developing instructional goals. To best explain what contributes to spelling abilities in college students, it seems the continuous analysis approaches held more explanatory power than the dichotomous assessment procedure.

Our findings have important research and clinical implications. First, the Levenshtein distance, for example, which was calculated with relative quickness and ease in R, a free statistical software program, may be useful for future research investigations aimed at precisely quantifying the spelling skills of adults. However, the Levenshtein distance scoring system only provides information on the difference between letters in the target word and the individual's spelling attempt of that word. It penalizes spelling attempts for letter omissions, substitutions, or additions. However, those types of errors can be due to deficits in phonological, orthographic, or morphological awareness; the analysis does not provide that information. The SSS approach, which assigns scores based on the linguistic properties represented in the spelling, provides information regarding the linguistic awareness skills that may or may not have been used to spell the words. Because the SSS provides information regarding the lack of application of linguistic awareness to spell words, it likely is more useful for developing instructional goals for a language-based approach to spelling instruction (e.g., Apel, Masterson, & Brimo, 2012). For example, using the SSS, spellings that earn a notably large number of "1" scores may indicate an orthographic awareness issue, which would provide treatment guidance for the practitioner. This type of guidance is not possible through dichotomous scoring or via the Levenshtein distance, which do not focus on the linguistic awareness skills used to spell. Further, the SSS has been found to be useful for monitoring the increased use of linguistic awareness skills as part of spelling progress in children because of its sensitivity to subtle improvements in an individual's spelling improvement (e.g., Bailey et al., 2017; Masterson & Apel, 2010b). It is reasonable to consider that this also may be a useful way for monitoring progress with adult spellings. Future investigations could examine whether and how instructional goals vary by the use of the different types of analyses, whether such goals lead to more efficient instruction, and which approach is best for monitoring spelling improvement.

Limitations

An essential limitation of the present paper is that there are few standardized measures of linguistic awareness appropriate for adults. Although steps were taken to maximize the reliability and validity of the assessments used to evaluate the participants' linguistic awareness skills, further work is needed to understand the utility of these tools. Without consensus on how to assess these different linguistic awareness skills, outcomes from different investigations may be as much of a result of the task used as they are of adults' abilities. Item analyses and dimensionality assessment with independent samples of participants are needed to understand what underlying abilities are being assessed by these tools and how they may vary for different samples of adults. This paper provides a foundation for this future work in demonstrating the potential relations among these linguistic awareness skills.

Our syntactic awareness task also may have measured, to some degree, the students' morphosyntactic abilities. Currently, there are a limited number of syntactic awareness measures that have been used with adults. Of those used, none have been studied for the potential overlain in measurement between syntactic and morphological awareness. Thus, future investigations could investigate how different measures of syntactic awareness, including those that may or may not assess morphosyntactic skills simultaneously, predict spelling in adults. Although some investigators have examined simultaneously the relation of several linguistic awareness skills on literacy abilities, to date, no research team has studied these four linguistic awareness skills simultaneously, making it difficult to determine the degree to which each skill explains variance in spelling outcomes when examined concurrently alongside the other linguistic awareness abilities.

We excluded participants who reported a history of reading difficulties and who a) either performed outside of the average range on one of our reading screeners or b) performed within the average range on one of the screeners, but 1.5 standard deviations or more below the mean on the other reading measure. The inclusion of participants with typical reading skills was intentional as a first step for understanding the relation between spelling error analyses and multiple linguistic awareness skills in college students with typical reading skills. According to the National Center for Education Statistics (2017), however, 11% of ninth grade students with a diagnosis of a learning disability in the ninth grade planned to pursue a postsecondary bachelor’s degree and 4.8% of college students self-report having a specific learning disability while in college. These numbers make our results somewhat limited concerning our understanding of the language and literacy skills of the general undergraduate student population. Future research comparing individuals with typical reading abilities and those who struggle to read in college would undoubtedly shed light on potential differences in their linguistic awareness skills and which methods may be best for assessing these skills.

Conclusion

The aim of this study was to evaluate the concurrent validity of dichotomous and continuous measures of spelling, as well as to determine the linguistic awareness predictors of spelling in college-aged adults. First, our findings indicated high concurrent validity between dichotomous scoring and continuous scoring of adults' spelling. This finding indicates that either spelling scoring system may be used with confidence to gain a broad picture of adults' spelling abilities. Second, our findings indicated that morphological awareness and syntactic awareness predicted adults' spelling performance for both the dichotomous and continuous scoring methods, but orthographic awareness and phonemic awareness predicted adults' spelling performance on only the continuous spelling measures. These findings indicate that (a) linguistic awareness is an important consideration when planning spelling instruction for college-aged adults, (b) continuous scoring of spelling may provide a more precise picture of the skills adults employ when spelling, and c) that it may be warranted for planning of instructional targets, particularly orthographic or phonemic awareness-based instruction.

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Table 2

Descriptive Statistics

Task	**_Raw Scores_** Mean (*SD*)	Range	Max Possible	**_Standard Scores_** Mean (*SD*)	Standard Error	Range
TOSWRF-2[1]	157.87 (*17.66*)	123 - 204		96.45 (*9.04*)	1.17	79 - 121
TOSCRF-2[2]	153.57 (*23.23*)	106 - 227		97.20 (*10.71*)	1.38	78 - 134
Morphological Awareness	11.10 (*3.45*)	1 - 16	16	--		--
Orthographic Awareness	9.35 (*1.29*)	4 - 10	10	--		--
Phonemic Awareness	6.93 (*4.89*)	0 - 16	21	--		--
Syntactic Awareness	17.35 (*4.46*)	6 - 26	32	--		--
Spelling (dichotomous)	14.27 (*5.67*)	4 - 28	30	--		--
Spelling: Element Score	2.78 (*0.11*)	2.46 - 2.97	3			
Spelling: SSS[3] Word Score	2.10 (*0.37*)	1.32 - 2.87	3	--		--
Spelling: Levenshtein Distance	1.03 (*0.50*)	0.13 - 2.50	0[4]	--		--

[1]TOSWRF-2 = Test of Silent Word Reading Fluency-2nd Edition

[2]TOSCRF-2 = Test of Silent Contextual Reading Fluency-2nd Edition;

[3]SSS = Spelling Sensitivity System

[4]A score of zero for the Levenshtein Distance indicates correct spelling.

Table 3

Models Predicting Student Spelling

Variables	9.	8.	7.	6.	5.	4.	3.	2.
1. **Morphological Awareness**	.656 ($p < .001$)	.688 ($p < .001$)	.668 ($p < .001$)	-.667 ($p < .001$)	.238 ($p = .067$)	.260 ($p = .045$)	.428 ($p < .001$)	.383 ($p = .002$)
2. **Orthographic Awareness (total)**	.208 ($p = .110$)	.311 ($p = .015$)	.313 ($p = .015$)	-.322 ($p = .012$)	.208 ($p = .111$)	.264 ($p = .042$)	.654 ($p < .001$)	
3. **Orthographic Awareness (0.71)**	.419 ($p < .001$)	.506 ($p < .001$)	.499 ($p < .001$)	-.500 ($p < .001$)	.214 ($p = .100$)	.179 ($p = .171$)		
4. **Phonemic Awareness**	.348 ($p = .006$)	.385 ($p = .002$)	.414 ($p = .001$)	-.419 ($p < .001$)	.073 ($p = .581$)			
5. **Syntactic Awareness**	.364 ($p = .004$)	.325 ($p = .011$)	.389 ($p = .002$)	-.382 ($p = .003$)				
6. **Levenshtein Distance**	- .903 ($p < .001$)	- .966 ($p < .001$)	-.965 ($p < .001$)					
7. **Spelling – Element Score**	.961 ($p < .001$)	.944 ($p < .001$)						
8. **Spelling – Word Score**	.911 ($p < .001$)							
9. **Spelling - Dichotomous**								

Table 4

Models Predicting Student Spelling

	Dichotomous Scoring				Element Scoring[1]				Word Scoring[2]				Levenshtein Distance[3]			
Predictors	*Est.*	*LB*	*UB*	*p*	*Est.*	*LB*	*UB*	*p*	*Est.*	*LB*	*UB*	*p*	*Est.*	*LB*	*UB*	*p*
(Intercept)	-6.13	-14.13	1.87	.139	230.97	216.48	245.46	<.001	54.74	7.24	102.24	.028	30.72	24.14	37.30	<.001
Morphological Awareness	**0.83**	**0.49**	**1.18**	**<.001**	**1.50**	**0.88**	**2.13**	**<.001**	**4.94**	**2.90**	**6.99**	**<.001**	**-0.74**	**-1.02**	**-0.45**	**<.001**
Orthographic Awareness	0.56	-0.34	1.46	.229	**1.86**	**0.23**	**3.49**	**.030**	**6.06**	**0.71**	**11.41**	**.031**	**-0.86**	**-1.61**	**-0.12**	**.026**
Phonemic Awareness	0.21	-0.01	0.43	.071	**0.56**	**0.16**	**0.96**	**.008**	**1.80**	**0.49**	**3.11**	**.009**	**-0.21**	**-0.39**	**-0.03**	**.028**
Syntactic Awareness	**0.26**	**0.02**	**0.50**	**.041**	**0.52**	**0.09**	**0.96**	**.022**	**1.78**	**0.35**	**3.21**	**.018**	-0.16	-0.36	0.04	.121
Observations	60				60				60				60			
Marginal R^2 / Conditional R^2	0.521 / 0.486				0.598 / 0.569				0.599 / 0.570				0.586 / 0.556			

[1]For scaling, participants' element scores were multiplied by 100.
[2]For scaling, participants' word scores were multiplied by 100.
[3]For scaling, the Levenshtein Distance scores were multiplied by 10.

Note. LB = lower bound of estimate; UB = upper bound of estimate. Predictors with p-values below the critical values computed through the Benjamini-Hochberg linear step-up procedure are bolded.