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An examination of the relationship between reading comprehension, higher-level and lower-level reading sub-skills in adults

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Abstract Using a large adult reading database, we examined the relationships between high-level and low-level reading skills and between multiple reading skills, general cognitive ability, and reading comprehension ability. A principal components analysis found partial dissociability between higher-level skills including reading comprehension, vocabulary and print exposure, and lower-level skills including decoding and spelling in adult readers. Furthermore, follow-up regression analyses showed that the high-level sub-skills (e.g., vocabulary and print exposure) were significantly better predictors of reading comprehension ability than the low-level skills (e.g., decoding and spelling) in adult skilled readers. These findings suggest that higher-level and lower-level skills are dissociable in adult skilled readers and that higher-level skills are more strongly related to comprehension ability in adults.

Keywords Reading skill · Comprehension · Vocabulary · Decoding

Introduction

Reading comprehension is a complex process that requires the coordination of bottom up word level skills and top down meaning processing skills. Much research over the past several decades has focused on the decoding component of this equation, demonstrating strong correlations between low-level decoding skills and reading comprehension (e.g., Shankweiler, 1989). More recent research has examined the unique contribution of higher-level skills to reading comprehension

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(e.g., Landi & Perfetti, 2007; Nation & Snowling, 1998; Yuill & Oakhill, 1991). The bulk of the research exploring both lower-level and higher-level contributions has been done with school age children, leaving the population of adults relatively ignored. Understanding reading compression and the skills necessary for adequate comprehension in adults will provide a more complete understanding of comprehension ability. This paper will briefly review findings from studies with children and adult poor readers that examine the relationship between comprehension and other relevant skills (e.g., decoding, working memory, and semantic processing) and the few studies that have looked at this relationship in skilled adults. Moreover, I report findings that further specify the relationship between lower-level and higher-level reading skills in skilled adult readers and on the relationship between low-level and high-level sub-skills and reading comprehension in adults.

Relationship between low-level decoding skill and reading comprehension

Comprehension requires accurate word decoding and recognition, thus, it is no surprise that decoding ability and word recognition skills are highly predictive of comprehension ability (Perfetti & Hart, 2001; Shankweiler et al., 1999). Although this is particularly true for young children whose word reading skills are still developing (Curtis, 1980), low-level skills such as decoding have also been shown to account for unique variance in comprehension ability in older children, even for skilled readers (Shankweiler et al., 1996). It should be noted the importance of decoding skill in these studies may in part be due to the deep orthography of English—a recent study involving Greek speaking 4th graders and found word reading skills (spelling, word and pseudoword reading accuracy, and fluency) to predict comprehension ability before verbal ability and vocabulary were taken into account, but not after (Protopapas, Sideridis, Simos, & Mouzaki, 2007).

Although the consensus is that low-level skill such as decoding play a large role in children, the picture is less clear for adults. Bell and Perfetti (1994) found that decoding (assessed by pseudoword reading) predicted a significant amount of variance (11%) after higher-level skills were partialled out for science texts, but for history texts decoding picked up a only a very small amount of the variance (1%), suggesting that decoding may only play an important role in comprehension when word reading is more difficult (i.e., when individuals are encountering many new vocabulary words, taxing both decoding and word recognition skill, as they would in a science text). However, conclusions from this study should be tempered due to the fact that this was a small sample study (<100 participants) that targeted low ability readers with different profiles rather than representing a wide range of reading skill. Lundquist (under review), again focusing on lower ability adults, found that college students who performed poorly, (75% or less correct on a decoding measure; the pseudohomophone choice task) also read connected text more slowly but were not significantly different from good decoders (95% or greater on the pseudohomophone choice task) in general comprehension ability, suggesting some dissociation between decoding and comprehension. Furthermore, Braze, Tabor, Shankweiler, and Mencl (2007), also with a population of less-skilled adult readers, found that word reading and pseudohomophone identification tasks failed to account for additional variance in

reading comprehension after listening comprehension was taken into account, whereas pseudoword reading still accounted for significant (18%) variance. However, this relationship was greatly reduced (6%) after vocabulary was added to the model.

Research examining the relationship between reading skills in *skilled* adult readers is less common. Examining skilled readers is critical for providing information about the relationship between comprehension and other reading skills in the absence of any deficit that would put an obvious limit on comprehension ability. Perfetti and Hart (2001) report data from a factor analysis, which sought to examine the relationship among multiple reading skills in adult skilled, average, and poor comprehenders (using a three-way comprehension score mean split). The authors found partial dissociations between low-level skills such as spelling and elision and higher-level skills such as comprehension and vocabulary for all three groups of readers. However, they found that the pattern of factor loadings was different for the less skilled readers such that an additional factor was required to explain a comparable amount of variance—for poor readers, phonological skills (e.g., elision) loaded on a separate factor from lexical skills (e.g., word identification)—for skilled and average readers, these were combined on one factor. The authors suggest, that for more skilled readers, lexical-level factors and phonological factors are linked, whereas for poor readers they are separate. The authors did not conduct any follow-up analyses to determine the relative contributions of each of the sub-skills after accounting for basic skills such as decoding and IQ, thus it is difficult to determine the degree to which each of the skills tested contributed to reading comprehension ability. More recently, Jackson (2005) examined the relationship between academic skills (e.g., ACT) and a variety of reading measures among a small sample of highly skilled adult university students. She found that reading measures clustered into three independent components—decoding accuracy, reading speed, and text comprehension. This finding is consistent with those of Perfetti and Hart (2001), pointing towards a dissociation between comprehension and decoding abilities in more skilled readers. Interestingly, these findings indicate a unique role for reading speed/fluency that is separate from decoding ability among highly skilled readers. This dissociation has been previously suggested in work with less-skilled readers and individuals with dyslexia (e.g., Wolf et al., 2002), but the contribution of fluency to comprehension has not been further investigated for skilled adult readers. One difficulty for interpreting Jackson's (2005) findings, as in the study reported by Perfetti and Hart (2001), is that she did not include any additional analyses (beyond the data reduction) in order to determine the degree to which decoding and fluency were able to predict comprehension ability after taking other measured skills into account.

Taken together, findings from studies that have investigated the relationship between multiple reading skills in children and adults indicate that the relationship between low-level reading skills and comprehension is dependent on the age and skill level of the participants. That is, for children and less-skilled readers low-level skills play a more prominent role in comprehension ability. However, although the studies that have examined skilled adult readers suggest a partial dissociation between comprehension and decoding it is difficult to determine the precise contribution of low-level skills to comprehension skill from these studies because regression models needed to examine partial contributions were not included.

Dissociation between comprehension and decoding in children

Skills other than decoding and word reading have been shown to predict comprehension in both children and adults. For example, skills such as the ability to hold information online in working memory, inference making, and comprehension monitoring have all been shown to be related to overall comprehension ability (see Perfetti, Landi, & Oakhill, 2005 for a review of this research). One complexity for interpreting the relative contribution of these higher-level skills to comprehension ability is that the research that has focused on higher-level contributions to comprehension failure has often failed to include appropriate decoding measures (Perfetti, 1985; Perfetti & Lesgold, 1979; Perfetti, Marron, & Foltz, 1996). For example, studies often include a "decoding" test that requires word reading in context, yet, context has been shown to have a bootstrapping effect on reading ability (Perfetti & Hogaboam, 1975). However, a growing body of work with children now has included appropriate decoding measures (word reading in isolation or non-word reading) and found reading and listening comprehension difficulties in some children with normal decoding abilities (Oakhill & Cain, 2000; Oakhill, Cain, & Bryant, 2003; Stothard & Hulme, 1995). Readers with this discrepancy are sometimes referred to as having Specific Comprehension Deficit (SCD), Specific Comprehension Impairment (SCI), or simply as poor comprehenders (see Perfetti et al., 2005). Researchers estimate that readers with SCD make up as much as 10–15% of readers in the seven to 8 year old age range (Stothard & Hulme, 1995). Recent studies have demonstrated that this particular group of children have trouble generating text appropriate inferences (Oakhill & Cain, 2000), monitoring their comprehension progress (Oakhill et al., 2003), using relevant semantic information (Nation & Snowling, 1998), processing syntactically complex sentences (Hagtvet, 2003), and holding information online in working memory (Oakhill et al., 2003), all despite adequate single word reading ability (see Nation, 2005 for a review of these findings). In light of the controls for adequate decoding ability in these studies, differences in reading and listening comprehension ability, working memory, and semantic processing must be accounted for by some other mechanism.

It is important to note, when comparing these findings with studies that identify decoding as an important predictor of comprehension skill (e.g., Shankweiler et al., 1996), that these studies test a relatively small percentage of the population of children who are specifically selected as having a discrepancy between decoding and comprehension. Thus, these findings are not inconsistent with findings of strong correlations between decoding and comprehension in school aged children—however, they do suggest that the strong relationship between these two skills does not hold for all children. Of great importance to ongoing research is to further refine the nature of the discrepancy between decoding and comprehension that exists in some children and to determine the prevalence of this discrepancy over development. For example, Catts, Adolf, and Ellis Weismer (2006) provided a developmental assessment of children with comprehension impairment by specifically comparing reading skills of children identified as poor comprehenders to those identified as poor decoders in kindergarten, second, fourth, and eighth grade. They found that eighth grade poor comprehenders (older children than had previously been studied) had

deficits in language comprehension but not phonological processing (with the opposite pattern for poor decoders). Furthermore, they found that children identified as poor comprehenders or poor decoders in the younger grades, including kindergarten had very similar reading skill profiles—although the discrepancy was larger in the later grades, suggesting that the dissociation becomes more prominent once children have transitioned to fluent decoding.

The primary aim of the current study was to identify whether a similar dissociation between comprehension (and other high-level skills, such as vocabulary) and low-level reading skills (such as decoding) exists in the adult population—as in children with SCD, and if so, to determine the nature and prevalence of this discrepancy. Furthermore, I sought to determine the relative contribution of multiple reading sub-skills, including, decoding, spelling, and print exposure as well as general cognitive skills such as non-verbal IQ to reading comprehension skill in adult skilled readers. Evidence reviewed above from Braze et al. (2007) and Lundquist (under review) suggests that decoding is not a good predictor of comprehension ability in adult less-skilled readers. Moreover, studies by Perfetti and Hart (2001) and Jackson (2005) are suggestive of a partial dissociation between comprehension and decoding. However, these studies (a) focused specifically on less-skilled readers, (b) had small sample sizes and/or (c) failed to include regression models to determine the relative contributions of low-level skills to reading comprehension ability. Moreover, none of these studies explicitly set out to determine whether a dissociation between low-level skills and high-level skills exists in adult readers.

Current study

The current study examined a very large database containing data from over 900 adult participants who took multiple reading tests designed to capture higher-level and lower-level reading abilities. In particular, I examined the factor structure of this database by determining which reading sub-skills (comprehension, vocabulary, decoding, and spelling) share the most variance. Additionally, I looked at the relationship between non-verbal IQ and experience (measured by print exposure) and these reading sub-skills. Furthermore, I report descriptive statistics that characterize the population of adult readers, including the frequency of adults who have discrepancies in their ability profiles. Finally, I also present data from regression models that quantify the contribution of higher-level and lower-level reading sub-skills as well as IQ to reading comprehension.

Methods

Participants

Nine hundred and twenty eight participants (Mean age = 20.17, SD = 3.69) at a public university in the northeastern United States took a battery of skill assessments (described below) over the course of the 2004, 2005, and 2006 academic years. This assessment was part of an ongoing screening procedure that

was used for subject selection for participation in subsequent studies. Participants were recruited through the introductory psychology pool and through the university newspaper. All participants were native English speakers, with normal or corrected to normal vision. Subjects were screened for epilepsy, history of reading disability, and brain injury. Participants were compensated with credit required for completion of their introductory psychology class or with one payment of seven dollars.

Procedure

The procedure for the study consisted of a series of skill assessments: All tests were given in paper and pencil format and were given in groups of approximately 25 participants. The Nelson–Denny (ND) vocabulary, ND comprehension, and Ravens Matrices tests were timed (see below) and participants were given the rest of a one and a half hour period to complete the other three tests. The tests and respective skills they measure are discussed in detail below.

Measures

Comprehension

The comprehension subtest of the Nelson and Denny (1973) required participants to read a paragraph and answer questions about the content of that paragraph. Participants chose one of five possible answers to each of 36 questions. Participants were given 15 min to complete the task. Participants received one point for every question they answered correctly and they received a one-fifth point deduction for each question they answered incorrectly or left blank. By using an equal deduction for wrong and blank answers, both speed and accuracy were taken into account in one measure.

Vocabulary

The vocabulary sub-test of the Nelson and Denny (1973) provided a word and asked the participant to select the correct definition from a list of five possible choices (participants repeat this procedure for each of 100 words). Participants were given seven and a half minutes to complete as many items as possible. As in the ND comprehension test, participants received one point for every question they answered correctly they received a one-fifth point deduction for each question they answered incorrectly or left blank.

Print exposure

To measure print exposure we used the Author Recognition Test or ART (Stanovich & West, 1989), which consists of a list of names, many of which were names of common authors. The participant's task was to correctly identify the authors and avoid making false alarms to non-author foils. The test contained 80 items and was not timed. Participant performance was measured by d' (z transform of hits − z transform of false alarms).

Decoding

To measure decoding ability of a large sample we used the pseudohomophone choice task (Olson, Forsberg, Wise, & Rack, 1994) which required participants to sound out written pseudo-words and answer whether or not they had the same pronunciation as a real word (e.g., *audishon*). The test contained 96 items and participants were not timed. The scoring method used for this test was a standard d' calculation. This test was used because it can be given in a large group setting. This test has been shown to correlate highly (.71) with the woodcock Johnson word attack measure, one of the most commonly used test of non-word decoding in the literature (Braze et al., 2007).

Spelling

The Baroff spelling test was used (see Frishkoff, Collins-Thomas, Perfetti, & Callan, 2008; Perfetti & Hart, 2001). This is a spelling discrimination task in which participants are presented with one correct and four incorrect spellings of irregular, easily misspelled words (e.g., *nuisance*, *nuisence*, *newsance*, *newcense*, *newsince*). Participant performance was measured by d'.

Non-verbal IQ

To obtain a measure of general intelligence that would not rely on verbal skills an abbreviated version of the Ravens Advanced Progressive Matrices was used (Raven & Raven, 2003). Participants were presented with a series of complex patterns and one incomplete pattern and were asked to find the missing part (select one of five choices) of the incomplete pattern. The test contained 18 total items (selected to represent the range of difficulty on the task), and participants were given 20 min to complete the test. This test was scored in the same manner as the ND vocabulary and comprehension tests with one point given for correct answers and a one-fifth point reduction taken for incorrect or blank answers. Again, as with the decoding measure, this test was chosen because it can be given in a group setting.

Results

Overall performance

There was a large range in performance for all of the assessments: Table 1 shows descriptive statistics from all assessment measures.

Correlations

Correlations between all measures were calculated. All correlations were significant (all $p < .05$); however, some correlations were stronger that others (Table 2). Significant correlations with comprehension ability, in order of correlation strength were: Vocabulary (.669), ART (.405), Spelling (.226), Ravens Matrices (.159), and

Table 1 Means, standard deviations and ranges for the age of participants and performance on the six measures

	Minimum	Maximum	*M*	SD
Age	18.00	49.00	20.17	3.69
Vocabulary	−11.60	96.40	41.99	18.50
Comprehension	−2.40	36.00	18.61	7.28
ART	−.13	.93	.29	.16
Decoding	−.06	1.02	.73	.19
Spelling	−.71	1.14	.79	.16
Ravens	−2.25	18.00	7.27	3.91

Table 2 Correlations between tasks

	Comprehension	ART	Decoding	Spelling	Ravens
Vocabulary	.669**	.463**	.181**	.298**	.167**
Comprehension		.405**	.092**	.266**	.159**
ART			.246**	.336**	.068*
Decoding				.379**	.105**
Spelling					.079*

* $p < .05$ level

** $p < .01$ level

Decoding (.092). The correlation with decoding seems particularly low in this analysis; however, it is not inconsistent with other findings that have used the same test with a similar population. For example, Lundquist (under review), report correlations between this specific test and comprehension that are below .2. This finding is also consistent with the relatively low correlation (.11) observed by Jackson (2005) between nonword reading [measured with the Test of Word Reading Efficiency (TOWRE)] and reading comprehension (Jackson, 2005). Higher correlations between decoding and comprehension are often seen in children for whom decoding is a nascent skill, but reports examining skilled adults suggest that these two skills are not necessarily strongly correlated. Braze et al. (2007) examined less-skilled adults and found a higher correlation between reading comprehension and the pseudohomophone choice task (.42), suggesting that for these individuals, who continue to struggle with reading, decoding may be a more significant factor.

Principal components analysis

In order to better characterize the structure of the data, a more complex measure that captures higher order correlations was employed. A Principal components analysis (PCA) was conducted on the data using a Varimax rotation with a Kaiser normalization (orthogonal solution) and was followed up with a Promax rotation (oblique solution). Using Kaiser's (1960) stopping rule, only eigenvalues greater than one were considered for component identification (see Bryant & Yarnold, 1995 for a review of PCA methods).

Table 3 Results of a Varimax rotated PCA with Kaiser normalization

	Component1: higher-level skills	Component 2: lower-level skills
ND comprehension	.881	.025
ND vocabulary	.868	.139
Author recognition	.608	.382
Ravens matrices	.297	.057
Decoding	.006	.864
Spelling	.265	.745

The PCA, with a Varimax rotation, identified two components that together accounted for 68.2% of the variance (47.5% by the first, and 20.7% by the second). In this analysis a conservative cutoff of .5 (factor loadings of .5 or greater) was used for inclusion in a particular component.[1] In general, the larger the factor score of a variable (i.e., test), the more likely that variable is to "belong" to that component. However, for factors to be independent it is important that variables have a "large" loading only for one component (Bryant & Yarnold, 1995).

In the first component (C1), comprehension, vocabulary, and author recognition had factor loadings greater than .5 (.869, .843, and .746, respectively), and decoding and spelling had factor scores lower than .5 (.059 and .225, respectively). In the second component (C2), Decoding and Spelling had factor scores greater than .5 (.847 and .743, respectively), and vocabulary, comprehension, and author recognition had factor scores lower than .5 (.157, .079, and .191, respectively; see Table 2). These results indicate that similar reading sub-skills underlie performance on comprehension, vocabulary and author recognition tests, and that these sub-skills are different from those reading sub-skills that underlie performance on decoding and spelling tasks. Furthermore, as Table 3 reveals, spelling skills contributed somewhat more to C1 than decoding skills did and that vocabulary, and author recognition contributed somewhat more to C2 than comprehension did. A PCA with a Promax rotation (allows intercorrelations) confirmed the findings of the Varimax PCA. Two factors were identified that together accounted for 68% of the variance (47.5% by the first factor and 20.7% by the second). In the first component, (C1), vocabulary, comprehension, and author recognition all had factor scores above .5 (.879, .866, and .745, respectively) and decoding and spelling sub-tests have factor scores below .5 (−.084 and .108, respectively). In the second component, (C2), decoding and spelling had factor scores above .5 (.872 and .735, respectively). A low correlation of .27 between the two factors in the Promax rotation supports the orthogonality of the two factors.

Despite the moderate correlations between all of the tests, the separation of test performance into two components suggests that there are two broadly defined "types" of reading skill. This separation also suggests that the tests identified within a component tap somewhat similar skills and that the tests that lie across components tap somewhat different skills. One question that arises is: what are the

[1] Some researchers consider values of .3 to load on a component; importantly, there were no variables that would have changed components if we had observed cutoff of .3.

percentages of participants that show a discrepancy between higher-level skills (C1) and lower-level skills (C2)? To investigate this question, two weighted factor composite scores were made for all participants by multiplying their normalized test scores (individual score − mean/SD) by the corresponding factor loading for each test and then averaging over tests (this was done for component one and for component two, thus providing a C1 score and a C2 score for each individual). For example, for each person's C1 score their vocabulary, comprehension, and ART scores were weighted more highly than their spelling and decoding scores, and vice versa for each person's C2 score. The scores for each person on each component were then plotted, and split by the mean score on both components to create four quadrants: high on both, low on both, high on one and low on two, and high on two and low on one (Fig. 1). As would be expected, individuals who scored above average on both or below average on both of the components were in the majority. However, a number of people had a discrepancy between their two scores when a simple mean split was considered. In particular, 130 out of 928 people (14%) scored at or above average on C2 but below average on C1 and only 87 (9.3%) of the individuals tested had the reverse discrepancy. This number, however, is greatly reduced when I impose a harsher cutoff for discrepant characterization—if I only consider individuals who fall beyond .5 standard deviations from the normalized mean on each component, there are only three individuals with better C2 than C1

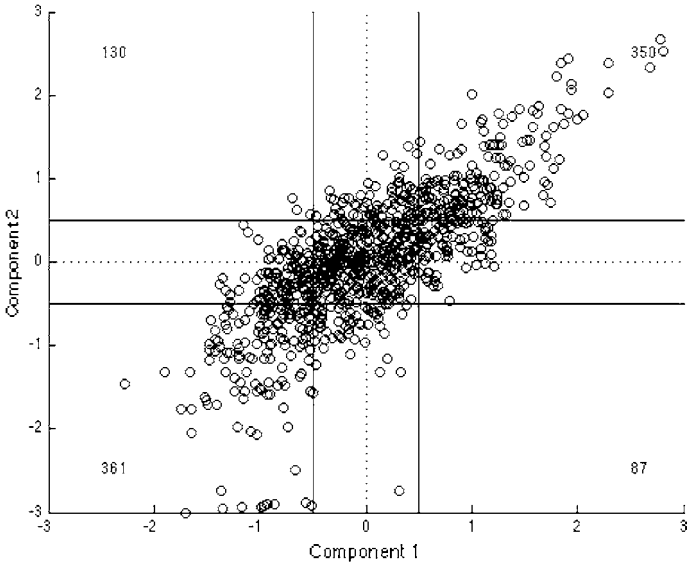

Fig. 1 Shows the relationship between Component 1(C1) and Component 2 (C2) scores for each participant. Component scores were created for all participants by multiplying their normalized test scores (individual score − mean/SD) by the corresponding factor loading for each test and then averaging over tests. The *solid lines mark* .5 standard deviations from the mean on each component. *Numbers* presented in the corner of each *quadrant* represent the number of individuals falling in each quadrant. Component 1 (C1) represents the C1 factor loading weighted composite score for vocabulary, comprehension, ART, decoding and spelling. Component 2(C2) represents the C2 factor loading, weighted composite score for comprehension, ART, decoding and spelling

performance and no individuals with the reverse discrepancy (see Fig. 1). This simple descriptive analysis suggests that within the adult population there are a number of individuals that have discrepant skill profiles (when a simple mean cutoff is used) and that there are somewhat more individuals with a discrepancy associated with poorer high-level skills and weaker low-level skills; however, the number of individuals with "discrepant profiles" in this sample is greatly reduced when a cutoff is used for discrepant classification. In sum, when component scores are used to assess discrepancy, there are not a large number of individuals with highly discrepant scores—in part this may reflect the multifaceted nature of these scores. Despite the relatively orthogonal, two-factor structure, some component skills were still more correlated with each other than others, moreover some skills loaded more clearly on one factor only than others (as can be seen in Tables 2, 3). Examination of the relationship between two scores alone (such as comprehension and decoding) may show more discrepancy; however, for the current analysis the primary concern was the relationship between high-level and low-level skills as defined by the PCA. Regression models in the next section further describe the relationship between individual skills.

Regression

A series of hierarchical regression analyses were conducted to determine any remaining contribution of low-level skills after accounting for vocabulary and print exposure. As Table 4a shows, vocabulary accounted for 45% of the variance, ART

Table 4 Regression analysis exploring the predictors of reading comprehension

Variables	R^2	Adjusted R^2	R^2 change	Sig. F change
(a) High level skills entered first				
1. Vocabulary	.45	.45	.45	.000
2. ART	.46	.46	.01	.000
3. Decoding	.46	.46	.003	.037
4. Spelling	.47	.46	.004	.006
5. Ravens	.47	.47	.003	.029
(b) Low-level skills entered first				
1. Decoding	.008	.007	.008	.005
2. Spelling	.07	.07	.06	.000
3. Vocabulary	.46	.45	.39	.000
4. ART	.47	.46	.01	.000
5. Ravens	.47	.47	.003	.029
(c) IQ entered first				
1. Ravens	.025	.024	.03	.000
2. Vocabulary	.450	.449	.43	.000
3. ART	.462	.460	.01	.000
4. Decoding	.465	.463	.003	.024
5. Spelling	.469	.466	.004	.007

only accounted for another 1.2% of the variance, and the lower-level skills of decoding and spelling (as well as the Ravens test) accounted for less than 1% of the variance. A second model was also tested, entering low-level skills first (Table 4b). Even when decoding is entered into the regression model first, it still accounted for less than 1% of the variance. Spelling accounted for 6%, vocabulary 44%, ART 1%, and Ravens <1%. These findings show that low-level skills such as decoding ability do not contribute very much to comprehension skill in this adult population. In this sample, this was true whether decoding was entered before or after high-level skills. One final model was analyzed entering IQ into the equation first (Table 4c). In this model IQ made a larger but still small (3%) contribution to comprehension ability. Predictions from low-level and high-level skills were similar to the first two models—vocabulary remained the strongest predictor of comprehension ability.

Discussion

These findings present evidence that adults' higher-level reading skills (comprehension and vocabulary) are partially dissociated from lower-level skills (spelling and decoding). This finding is consistent with Jackson (2005), Lundquist (under review), and Perfetti and Hart (2001). Moreover, print exposure clustered with higher-level skills, suggesting a strong relationship between experience and comprehension ability. Non-verbal IQ, however, was not associated with higher-level reading or lower-level reading skills in this sample, suggesting that for skilled readers both lower-level reading skills and higher-level reading skills are independent of IQ.

Finally, the regression analyses suggest that decoding accounts for only a very small amount of the variance in comprehension ability (<1%) in this sample of adults, even when decoding is entered before higher-level skills. This result differs somewhat from that of Braze et al. (2007) who found decoding to be a moderate predictor (accounting for 11%) of the variance before vocabulary was entered into the equation and a weak predictor (accounting for $\sim$1%) after entering in vocabulary. One difference between the current study and theirs is that they specifically sought out participants that were likely to have poor literacy skills (most from community colleges) and the current population attended a traditional university. Moreover, this finding is also different from findings with young children who have reading difficulty (e.g., Shankweiler et al., 1999), that have identified a very high correlation (.79) between decoding and comprehension. This difference is consistent with the hypothesis that decoding has a larger impact on comprehension ability when overall reading ability is low (Bell & Perfetti, 1994).

These results further support the hypothesis that word knowledge is critical for good comprehension. Vocabulary is the single best predictor of comprehension ability (accounting for approximately 40% of the variance in a hierarchical regression); it has the highest correlation with comprehension ability, and it clusters strongly with comprehension in the PCA. This result is consistent with the findings of Braze et al. (2007) and Lundquist (under review) who also found vocabulary to be a strong independent predictor of comprehension skill in adults and with several

studies with children that found high correlations between vocabulary knowledge and comprehension skill (Cunningham & Stanovich, 1991; Catts et al., 2006; Nation & Snowling, 1998 and in Greek, Protopapas et al., 2007). This relationship has been further refined in a recent study by Wagner, Muse, and Tannenbaum (2007) that specifically identified vocabulary breadth as critical for comprehension.

The current study did not reveal a large contribution from spelling ability (<1%) after decoding was taken into account or a large contribution from nonverbal IQ, which even when entered first only accounted for 3% of the variance in comprehension ability. When IQ was entered after either the low-level or high-level skills it accounted for <1% of the variance. The fact that IQ was a poor predictor is consistent with other studies that look at predictors of comprehension ability (e.g., Cutting & Scarborough, 2006). However, this sample was relatively homogenous in terms of general cognitive ability—samples that include a broader range of skill level may find IQ to be a better predictor of comprehension ability.

It is important to note that the use of other tests may have produced somewhat different findings—there has been a significant amount of recent research on assessment of reading comprehension that suggests that the choice of a specific comprehension measure and even the general type of comprehension measure can have important implications for comprehension research (see Fletcher, 2006; Francis, Fletcher, Catts, & Tomblin, 2005 for recent reviews of this literature). For example, Cutting and Scarborough (2006) have shown that the choice of reading comprehension measure has an impact on the measured relationship between comprehension and other skills. Specifically, they find that tests of comprehension do not all tap the same underlying language skills and cognitive processes and thus can be differentially influenced by particular skills. Moreover, Keenan and Betjemann (2006) investigated performance on the Gray Oral Reading Test (GORT), a common multiple choice comprehension measure, and found that children were above chance even when they did not actually read the passages. This suggests that many of the questions can be answered using prior knowledge alone and point out that students are likely to perform above their actual comprehension ability. Thus, the choice of a simple multiple choice comprehension test such as the GORT (and possibly other multiple choice/passage comprehension tests such as the Nelson–Denny) may not be ideal for assessing all aspects of comprehension skill. New models and tests of comprehension that are research based and are able to distinguish more accurately between sub-skills (e.g., the Diagnostic Assessment of Reading Comprehension [DARC]; August, Francis, Hsu, & Snow, 2006) will improve our ability to accurately assesses comprehension, and to distinguish comprehension from other reading skills such as decoding and fluency. The current data strongly support the need to test high-level skills independently of low-level skills. In addition to tests like the DARC, which attempt to isolate sub-skills relevant for comprehension, data presented here support the framework proposed by Catts et al. (2006), based on the simple view of reading that suggests a system that classifies readers based on their relative strengths and weaknesses in both word recognition and comprehension.

Moreover, the decoding measure used in this study, the pseudohomophone choice task, may be a sub-optimal measure of decoding. A one-on-one administered test of difficult non-word reading may have been more challenging, thus, these data

may slightly underestimate the contribution of decoding. However, Jackson (2005) used such a difficult nonword reading task with skilled adult readers and found similar strong dissociations between decoding and comprehension. Furthermore, as previously discussed in this article, the pseudohomophone choice task has been shown to correlate highly with other one-on-one tests such as the TOWRE (Braze et al., 2007).

Also note that the tests of comprehension and vocabulary used in this study are not necessarily pure measures of these respective skills; both require reading and include time as a factor in their analysis leaving open the possibility that fluency may affect performance on these tasks—but, if anything, this would likely have lead to an underestimation of the discrepancy between word decoding skill and comprehension. However, as Jackson (2005) demonstrates, fluency is an important and potentially independent factor that contributes to comprehension skill. Thus, we cannot assume that fluency will pair with or be subsumed by measures of other low-level skills. The relationship between fluency, vocabulary, and comprehension, particularly in skilled readers, remains a complex one and further research is needed to examine the relationship between comprehension and fluency in this population. Furthermore, with respect to the vocabulary assessment used here, significant research suggests that vocabulary can be measured in multiple ways, and that breadth and depth of knowledge are meaningful distinctions that may differentiate reader's vocabulary abilities (e.g., Nagy & Herman, 1987; Wagner et al., 2007). Certainly these sub-components of vocabulary may make differential contributions to comprehension skill, particularly in terms of the role of general knowledge and inference making as well as semantic processing ability in comprehension. Greater examination of the multidimensional nature of vocabulary and comprehension will improve our understanding of the strong coupling of these skills.

Finally, the tests included in this battery are far from exhaustive; other than IQ, I did not examine additional skills that are likely to be important for reading comprehension, such as working memory, phonological analysis, semantic processing, fluency, and listening comprehension. This absence of other measures was due in part to the method of data collection, which was done in groups, in paper-pencil format in order to ensure a large sample size. These other skills likely contribute significantly to comprehension ability, depending on the particular population being tested (e.g., listening comprehension is one of the best predictors of reading comprehension; Cutting & Scarborough, 2006; Gough & Tumner, 1986; Hoover & Gough, 1990). However, some of these un-tested skills may be subsumed by higher-level skills like vocabulary. For example, recent work shows that working memory does not contribute to comprehension ability once vocabulary and decoding have been accounted for in children (Cutting & Scarborough, 2006) and in adults (Braze et al., 2007). This may be due to the fact that working memory tasks tend to draw heavily on phonological processing (Waters & Caplan, 1996), and this variance is likely to be subsumed by decoding ability. Working memory tasks also draw heavily on semantic skills (Marshal & Nation, 2003) and this variance may be subsumed by vocabulary.

Taken together, these findings join other research showing that reading sub-skills other than decoding affect comprehension—and that in skilled adult readers

decoding is not a good predictor of comprehension skill. These findings are consistent with theories that focus on various high-level sources of differences in comprehension skill (Gernsbacher, Varner, & Faust, 1990; Nation & Snowling, 1998; Oakhill et al., 2003). In addition to the demonstration of a dissociation between lower-level and higher-level reading skills, I also show that decoding and other low-level skills such as spelling make only a very small contribution to the prediction of comprehension skill, and that vocabulary is the best predictor of comprehension ability in skilled adult readers. Because of the importance of vocabulary in my analysis, the results are especially consistent with hypotheses that emphasize word meaning (Nation & Snowling, 1998) or lexical quality (Perfetti, 2007; Perfetti & Hart, 2001) in comprehension, reinforcing the importance of lexical-semantic knowledge for adult readers with adequate decoding skills. However, future research is needed to tease apart the relationship between lexical-level semantics and comprehension level semantics, which incorporates pragmatics and syntax as well as the ability to integrate general knowledge with text and form a situation model. These findings are also largely consistent with the simple view of reading (Hoover & Gough, 1990), which posits that reading comprehension is the product of listening comprehension and decoding (see also Catts et al., 2006; Kirby & Savage, 2008 for recent tests and interpretations of the theory). From this simple equation it follows that, factors that contribute to general comprehension will account for the remaining variance in reading comprehension skill after decoding has been accounted for; thus, when skilled readers (with good decoding skills) are the test population, these general comprehension skills will subsume most of the variance in reading comprehension. This paper adds to a growing body of literature that reinforces the need to better understand factors that contribute to comprehension skill. I also want to emphasize that these findings are consistent with the notion that for most adult readers, and many children who have passed the transition to fluency stage, decoding ability is not a limiting factor in reading comprehension skill.

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