Reading comprehension components and their relation to writing

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ABSTRACT

Within the educational community, research on student literacy often combines reading and writing measures, as they are presumed to draw on similar skills and background knowledge. However, relatively few studies have investigated the underlying cognitive skills required for both activities, and to what extent the required background knowledge and cognitive processes overlap. The current study investigates how individual differences commonly related to reading comprehension ability overlap and contribute to students' writing proficiency. University students ranging from 19 to 37 years old (n = 108) completed assessments to examine their reading comprehension and writing skills, as well as their vocabulary knowledge, lower-level cognitive skills (working memory), and higher-level cognitive skills (text memory, text inferencing, knowledge access, knowledge integration). Results indicated that reading comprehension was strongly related to both vocabulary knowledge and the higher-level cognitive skills. Further, writing ability was moderately associated with a subset of the measured variables, namely vocabulary knowledge and the ability to access prior knowledge. These results support the hypothesis that reading comprehension and writing share common knowledge sources and higher-level cognitive skills, although the writing process is much less reliant on these measured variables than reading comprehension.

Les composants de la compréhension en lecture et leur relation à la production d'écrits

RÉSUMÉ

Dans la communauté éducative, les recherches en littéracie combinent souvent des évaluations de la lecture et de l'écriture, ces deux habiletés étant présumées reposer

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sur les habiletés et connaissances communes. Cependant, peu de recherches ont étudiés simultanément les habiletés cognitives impliquées dans chaque activité et dans quelles mesure ces processus et connaissances se recouvrent. La présente recherche a pour objectif d'étudier comment les différences interindividuelles communément associées à la compréhension en lecture contribuent aussi aux performances de production écrite. Une série d'épreuves a été administrée à étudiants âgés de 19 à 37 ans (n = 108) afin d'évaluer leur compréhension en lecture, leurs habiletés d'écriture, leur vocabulaire ainsi que leurs habiletés cognitives élémentaires (mémoire de travail) comme de plus haut niveau (mémorisation de textes, capacité inférentielle, accès et intégration des connaissances). Les résultats indiquent que la compréhension en lecture est fortement liée au vocabulaire et aux habiletés cognitives de haut niveau. La production est également modérément associée à un sous ensemble des variables mesurées : le vocabulaire et la capacité à accéder aux connaissances en mémoire. .Ces résultats sont en faveur de l'hypothèse selon laquelle la compréhension en lecture et la production d'écrit partagent des sources communes de connaissances et certains processus cognitifs de haut- niveau, le processus de production écrite dépendant toutefois moins fortement que la compréhension, des variables étudiées dans cette recherche.

1. INTRODUCTION: THEORETICAL IISSUES

In today's society, the ability to read and write is crucial for communication with the surrounding environment. With the increasing volume of electronic messaging, online news stories, and other printed sources of information, strong literacy skills are more important than ever. Unfortunately, despite this apparent need, assessments consistently report ubiquitous student underachievement in the literacy domain. This problem has been particularly poignant in the United States, where according to the National Assessment of Educational Progress (2011) only 27% of eighth graders and twelfth graders score at or above proficiency levels in writing, and only 3% of these students score at advanced levels (NAEP, 2011). Comparable findings have been reported for reading, with only 32% of eighth grade and 38% of twelfth grade students scoring at or above reading proficiency (NAEP, 2009). Similar problems persist in many countries across the world with international assessments of literacy suggesting that students, on average, only have intermediate levels of literacy proficiency (e.g., Baer & McGrath, 2007).

One way that educators and researchers have attempted to alleviate these proficiency gaps is by identifying the skills and background knowledge required for the successful comprehension and production of text. Indeed, a good deal of research has focused on the shared *knowledge* required to complete both reading and writing tasks (e.g., knowledge about vocabulary

or prior world knowledge; for reviews, see Galda, 1983; Shanahan, 1988; Stotsky, 1983). Along these lines, some researchers hypothesize that the identification of these common factors and the integration of reading and writing instruction is essential to informing classroom practices designed to enhance literacy skills (Corden, 2007; Couzijn, 1999; Parodi, 2007).

Extensive research has identified a number of cognitive processes involved in reading comprehension (Daneman & Carpenter, 1980; Gernsbacher, 1997; Graesser, Singer, & Trabasso, 1994; Kintsch, 1998; McNamara, Jacovina, & Allen, in press; Myers & O'Brien, 1998; Zwaan, Langston, & Graesser, 1995). These processes range from lower-level skills, such as working memory, to higher-level cognitive skills, such as generating inferences based on background knowledge. Although these constructs have been thoroughly examined within the domain of reading comprehension (Daneman & Carpenter, 1980; Gernsbacher, 1997; Graesser et al., 1994; Kintsch, 1998; Myers & O'Brien, 1998; Zwaan et al., 1995), relatively little is known about how these higher-level skills overlap with writing proficiency. The current work draws from previous research on reading comprehension to examine how lower- and higher-level cognitive skills (in addition to vocabulary knowledge) relate to comprehension and, in turn, how these skills map onto students' writing ability. Specifically, we aim to confirm relations between lower and higher-level cognitive skills and reading comprehension ability, and further to examine how these same processes potentially relate to writing proficiency. The overall motivation for this study is driven by the hypothesis that reading comprehension and writing share components (e.g., background knowledge, cognitive skills, etc.) that can be leveraged to provide more effective interventions for struggling students.

1.1. Theoretical Models of Reading Comprehension and Writing

A number of discourse models have been proposed to account for the cognitive processes that allow a reader to collect information from a text and develop a comprehensive understanding of that text at various levels (Gernsbacher, 1997; Graesser et al., 1994; Kintsch, 1998; Myers & O'Brien, 1998; Zwaan et al., 1995). While these models diverge in more specific components, the majority of contemporary comprehension models highlight the *constructive* and *active* nature of the reading comprehension process. For instance, Kintsch, in his construction-integration model, theorizes that reading comprehension involves *recalling* information from

the surface and deeper levels of the text and generating a *situation model,* where background knowledge and experiences are *integrated* into the text for a specific purpose (Kintsch, 1998). Thus, according to these models, reading comprehension relies not only on the background knowledge of the reader, but also on the cognitive processes necessary to capitalize on this existing knowledge.

A number of models have also been developed to account for the cognitive processes involved in writing. One of the most influential conceptualizations of the writing process came from Hayes and Flower (1980), who outlined the individual levels of information processing that are involved in the production of text. Importantly, this model is nonlinear and emphasizes the *interactions* that can occur among the writing processes (e.g., planning and translating), the task environment (e.g., assignment and audience), and the information in the writer's long-term memory (e.g., knowledge of the topic). This model was later revised to account for more recent research in cognitive science and writing (Hayes, 1996). Namely, a working memory component was added to the model and there was a stronger emphasis on the writer's motivation to communicate during the writing process. Overall, both models had a strong impact on the field of writing research because they introduced writing as a nonlinear information-processing task that is reliant on a limited capacity cognitive system.

The majority of contemporary writing models emphasize the role of lower-level cognitive skills (e.g., working memory), as well as background knowledge; yet, they rarely discuss the role of the higher-level skills that are intended to make use of this background knowledge (e.g., integrating knowledge or generating inferences). It is not a stretch, however, to modify the constructive and active aspects of text *comprehensio*n theories to apply to processes of text *production.* For instance, throughout the writing process, a writer typically *constructs* meaning through a combination of their prior knowledge (e.g., about the world, domain, language) and experience, and works to *integrate* this knowledge into a coherent structure that is appropriate for a particular audience. The similar constructs shared between text generation and production provide sufficient grounds to investigate the higher-level cognitive skills that are both shared and unique to the tasks of reading comprehension and writing. Specifically, research on literacy and the reading-writing connection can be substantially enhanced with investigations that are not only based on the knowledge required to complete literacy tasks, but also on the higher-level cognitive skills that are associated with accessing and efficiently using this knowledge.

1.2. Connections between Reading Comprehension and Writing Proficiency

Previous research on the reading-writing connection has focused primarily on informing pedagogy with the underlying goal of enhancing students' performance on literacy tasks. One purpose of earlier studies in this vein was to identify and assess relationships between reading and writing. Accordingly, a number of studies have been conducted to investigate reading-writing relations from various perspectives (e.g., background knowledge, procedures, strategies, etc.). Researchers have subsequently attempted to use these findings to integrate various aspects of reading and writing instruction (Clarke, 1988; Graham & Hebert, 2011; Straw & Schreiner, 1982).

Although the research on reading-writing connections remains relatively sparse regarding the role of lower- and higher-level cognitive skills, a limited number of studies have identified cognitive skills that are necessary for reading comprehension and writing tasks (both separately and in combination). Lower-level skills, such as working memory capacity, have been linked to performance on both reading comprehension and writing tasks (Berninger, Cartwright, Yates, Swanson, & Abbott, 1994; Daneman & Carpenter, 1980), and a number of higher-level cognitive skills have been examined in relation to reading comprehension performance (e.g., Bloom, Fletcher, van den Broek, Reitz, & Shapiro, 1990; Chabot, Zehr, Prinzo, & Petros, 1984; Hannon & Daneman, 2001; Masson &Miller, 1983; Singer & Richot, 1996). Prior research, however, has rarely (if ever) simultaneously examined the impact of lower- and higher-level cognitive skills on reading comprehension and writing performance. Such investigations are critical for the advancement of theoretical understandings of literacy as a whole, as well as for the development of literacy curriculum that is sensitive to similarities and differences between reading comprehension and writing processes.

1.2.1. Shared Knowledge

To understand how to most effectively develop an integrated pedagogy for reading comprehension and writing, educators must understand what background knowledge is shared between each task and what knowledge is unique. In their review of the literature, Fitzgerald and Shanahan (2000) classified four knowledge bases as common factors across both reading comprehension and writing: meta-knowledge, domain knowledge, knowledge about universal text attributes, and procedural knowledge.

"Meta-knowledge" involves knowing about the purpose of reading comprehension and writing, understanding the interaction between readers and writers, and monitoring one's own comprehension and knowledge. This form of knowledge has been positively linked to both reading comprehension and writing in previous studies (Langer, 1986; Shell, Colvin, & Bruning, 1995). "Domain knowledge" refers to one's prior knowledge about a given content area, as well as the knowledge that may be gained during the reading comprehension or writing processes (e.g., word meanings learned through context). "Knowledge about universal text attributes" includes a reader or writer's understanding of syntax and discourse (e.g., schemata knowledge), along with their knowledge of specific language features, such as phonemes and morphology. Finally, "procedural knowledge" that is shared across reading comprehension and writing typically involves the skills needed to construct meaning from, or with, a text (Langer, 1986). This can include primarily automatic processes, such as the recall of information from memory, or deliberate strategies, such as developing analogies or questioning given information (Kellogg, 1994).

A number of studies have investigated shared knowledge between reading comprehension and writing using assessments related to both the surface and deep levels of text (e.g., vocabulary knowledge, text cohesion, etc.; for reviews, see Galda, 1983; Shanahan, 1988; Stotsky, 1983). These studies have typically involved measuring one aspect of reading (e.g., holistic comprehension score, vocabulary knowledge), along with one for writing (e.g., holistic writing score, organization, grammar), and reporting the correlation between the variables. The reported correlation serves as evidence for a connection between reading and writing. In a review of the literature, Tierney and Shanahan (1991) reported consistently moderate to strong correlations between various measures of reading and writing (though typically never exceeding $r = .50$).

One of the earliest and most extensive studies of the reading-writing connection was a longitudinal study that followed over 300 students from kindergarten until their high school graduation (Loban, 1963; Loban, 1967). Data were collected for each student on reading, writing, and listening abilities, along with various other aspects of their language use. Loban (1967) reported a strong relationship between reading and writing, finding that poor readers were also poor writers, while good writers were also good readers. Specifically, he reported that all students who ranked superior in writing ability ranked above age level in reading; additionally, all students who ranked illiterate in writing ranked below age level in reading.

Following the successful results of Loban's study, numerous researchers continued to investigate the shared background knowledge found across

reading comprehension and writing (e.g., Abbott & Berninger, 1993; Berninger, Abbott, Abbot, Graham, & Richards, 2002; Juel, Griffith, & Gough, 1986; Shanahan, 1984). Abbott and Berninger (1993), for instance, investigated the relationships between potential latent factors underlying the writing development of over 600 elementary school students. They found correlations ranging from $r = .22$ to $r = .54$ between writing quality and reading comprehension ability. Similarly, Juel et al. (1986) conducted a longitudinal study that followed students from first to second grade and analyzed the reading-writing relationship at multiple levels of text, including spelling, word recognition, reading comprehension, and writing ability. They concluded that the lowest-level aspects of reading and writing (e.g., word recognition and spelling) relied upon similar knowledge bases, such as phonemic awareness and vocabulary knowledge, but the higher-level abilities (e.g., comprehension and production) relied upon different, yet somewhat overlapping, knowledge bases (e.g., discourse knowledge, strategic knowledge).

Although correlations between knowledge sources related to reading and writing have been fairly consistent across age and text levels (Fitzgerald & Shanahan, 2000), even higher correlations have been found by researchers using multiple measures to capture individual text aspects (e.g., vocabulary knowledge, text comprehension, and coherent text production). For example, Berninger et al. (2002) investigated connections between reading and writing as part of a larger research project comparing language by hand (reading and writing) to language by eye (listening and speaking). They administered multiple measures of each factor, yielding shared variances of up to 85% for word recognition and spelling factors, and up to 66% for surface-level text comprehension and production. Their results indicated that reading had a greater influence on writing than writing had on reading, but that both skills were strongly related across multiple grade levels.

1.2.2. Shared procedures and strategies

Prior research on the reading-writing connection has typically neglected to examine the specific procedures and strategies that are involved in both literacy tasks; however, this issue has begun to receive more attention. Specifically, researchers have investigated overlapping steps, procedures, and strategies employed by students during both reading comprehension and writing tasks, such as summarizing information, developing hypotheses, and making connections about the text (Birnbaum, 1982; Martin, 1987; Shanahan, 1984; Tierney, 1983). The majority of

the data from these studies involve think-aloud protocols, interviews, or classroom observations. Therefore, the results are predominantly qualitative in nature.

Ryan (1985) analyzed the verbal protocols of eight students who were above average proficiency in both reading and writing. She identified six strategies that were common to reading comprehension and writing for these students: reporting (paragraphing), conjecturing (hypothesizing, predicting), contextualizing (creating scenarios, imagining), structuring, monitoring, and revising. In a similar analysis, Kirby (1986) analyzed videotapes of five basic-level students and found that, throughout the reading comprehension and writing processes, these five students more frequently exhibited similar rather than different strategies. For example, if the students failed to plan when composing a text, they similarly failed to set goals and plan before reading. She concluded that many of the shortcomings of students while reading or writing were similar across both tasks.

In one of the largest studies of the reading and writing connection to date, Langer (1986) investigated the reading and writing behaviors of 67 students in the third, sixth, and ninth grades. She analyzed shared background knowledge, as well as monitoring, reasoning, and strategy use during students' reading and writing of stories and reports. She found that students' behaviors differed as a function of their age and the difficulty of the specific task. Additionally, she found that reading comprehension and writing called upon a number of similar cognitive processes, such as reasoning and constructing meaning. However, while both reading comprehension and writing were associated with similar processes, there were strong differences in the frequency and nature of their use. For instance, there was a stronger focus on surface-level text issues, such as syntax, vocabulary, and mechanics when writing, as compared to reading. Langer concluded that while reading and writing are similar constructs, they have vastly different origins. For instance, readers are constrained by an author's particular word choice, rhetorical style, and content when generating meaning from a text. Writers, on the other hand, have fewer constraints and can more freely draw information from their own background knowledge of a topic.

1.2.3. Working memory

From the cognitive perspective, research has predominantly investigated the role of lower-level skills, such as working memory, on both reading comprehension and writing performance tasks. Significant correlations have consistently been reported between individuals' working memory

scores and their performance on higher-level cognitive tasks such as following directions, note taking, and learning to write computer programs (Engle, 2002). Specifically, researchers have pointed to the role of working memory in the comprehension (Daneman & Carpenter, 1980; Engle, Cantor, & Carullo, 1992; Yuill, Oakhill, & Parkin, 1989) and production of text (Berninger & Swanson, 1994; Kellogg, 2008; McCutchen, 1996). For instance, in a longitudinal study of 7-year-old children, Oakhill, Cain, and Bryant (2003) showed that scores on working memory tasks accounted for significant variance in scores on reading comprehension tasks. Similarly, Berninger et al. (1994) identified significant relations between the working memory capacity and writing ability of fourth, fifth, and sixth graders. Only a relatively smaller number of studies have *simultaneously* investigated the role of working memory capacity on both reading comprehension and writing tasks. In one such study, Babayigit and Stainthorp (2011) followed two groups of children (2nd grade and 4th grade) for one year (into the 3rd and 5th grades, respectively). Students' completed a battery of assessments that were intended to measure the component processes of reading fluency, spelling accuracy, reading comprehension and narrative text writing. Results of this study indicated that working memory was moderately related to both reading comprehension and writing at both time points; however, working memory capacity failed to make unique contributions when other measures, such as vocabulary, were considered.

Importantly, the majority of these studies utilized working memory tasks that required participants to utilize some skills that are intrinsically related to reading comprehension and writing ability (e.g., vocabulary knowledge). Studies that have used other measures of working memory (i.e., non-reading-based measures of working memory), on the other hand, have typically failed to report similar correlations between working memory scores and literacy performance (Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Dixon, LeFevre, & Twilley, 1988). Thus, the specific role of working memory on reading comprehension and writing proficiency remains unclear among educational and cognitive researchers.

Overall, these studies are only a small subset of the large body of literature revealing the strength of connections between reading comprehension and writing. Based on these studies and extensive reviews of the literature (Nelson & Calfee, 1998; Shanahan & Tierney, 1990; Tierney & Shanahan, 1991), it is clear that both literacy skills draw upon similar procedures and knowledge bases. What many of these studies lack, however, is a focus on the shared *higher-level* cognitive skills between reading comprehension and writing. Thus, it is still relatively unclear how higher-level cognitive skills relate to performance across both literacy tasks.

1.2.4. Higher-level cognitive skills

Research on the relations between reading comprehension and writing has placed less of an emphasis on the role of higher-level cognitive skills. Although there is a large body of literature that examines the role of such processes for reading comprehension (e.g., Hannon & Daneman, 2001), much less is known about how these processes play a similar or different role in the writing process. Reading comprehension researchers have attempted to isolate the "component processes" (i.e., individual processes) that allow a reader to develop meaningful and coherent representations of the texts that they are reading (i.e., using knowledge about the world and in the text to develop a deep understanding of a concept). In multiple studies, a cognitive component processes task developed by Hannon and Daneman (2001) has emerged as a strong method of predicting students' reading comprehension abilities, accounting for over 60% of the variance in standardized reading comprehension measures (Daneman & Hannon, 2001; Hannon, 2012; Hannon & Daneman, 2006). This component processes test provides measures of four cognitive abilities: access of prior knowledge from long-term memory, integration of prior knowledge with new information in a text, making inferences based on information in the text, and the ability to recall new information from memory. Research has demonstrated the relationship of these four components to text *comprehension*, but not to text *production.* In light of the constructive theories of comprehension and production, however, it may be reasoned that these component processes might reflect important similarities and differences between the higher-level cognitive skills underlying both literacy tasks.

The ability to access prior knowledge from long-term memory has been previously tied to achievement on reading comprehension tests. Chabot et al. (1984), for instance, investigated the relations between word recognition, lexical access, and semantic memory access to reading comprehension scores. They found that reading scores were most highly influenced by students' ability to quickly access their semantic memory. Similarly, the integration of prior knowledge with new information has been found to be a considerable source of individual differences in reading comprehension ability (Singer & Richot, 1996). Numerous taxonomies for inferences in reading comprehensions have been proposed, with little consensus among researchers (Graesser et al., 1994). However researchers have rarely contested that the ability to make inferences based upon information in the text can lead to improved performance in comprehension (Bloom et al., 1990). Finally, Masson and Miller (1983) found that the ability

to remember the information provided in a text is directly related to comprehension of that text. Overall, these components have strong empirical ties to proficiency in reading comprehension. Thus, due to the similar *constructive* and *meaning-making* nature of both reading and writing, these components may be an area of shared variance between both processes.

2. CURRENT STUDY

The current study investigates how students' lower- and higher-level cognitive skills relate to their performance on reading comprehension and writing tasks. Specifically, we examine the degree to which cognitive skills that are associated with the construction of meaning contribute to both reading comprehension and writing performance. Importantly, this study is specifically focused on the reading *comprehension* process. Therefore, we do not aim to make claims about more general and low-level reading tasks, such as the process of decoding or processing syntax. In this study, we first confirm the relationship of cognitive skills to reading comprehension performance and then examine the degree to which these skills play similar or unique roles in writing proficiency.

3. METHOD

3.1. Participants

The participants were 108 undergraduate college students from a university located in southwestern United States. The students were between 18 and 37 years of age ($M = 19.75$), and the majority of the participants were either in their first or second year of college. Of the 108 students, 48.1% were female; 53.7% were Caucasian, 22.2% were Hispanic, 10.2% were Asian, 3.7% were African-American, and 9.3% reported "other." Additionally, 25.9% of the students reported that they were second language speakers of English, while 74.1% reported that they were native speakers. Importantly, all students were enrolled in regular classes at the university; therefore, the English as a Second Language (ESL) students had strong enough English skills to perform regular, non-ESL coursework. The participants were recruited through the psychology department participant pool and given credit in their Introductory Psychology course for participation in the study. Seven participants had missing Aospan data due to computer failure. The data for these participants were analyzed using pairwise deletion.

3.2. Materials

3.2.1. Demographics Questionnaire

The participants completed a questionnaire including questions about their age, year in college, gender, ethnicity, and native language.

3.2.2. Writing Performance Assessment

Each student wrote a timed (25-minute), prompt-based, argumentative essay.

3.2.2.1. Essay prompt

The essays were written in response to a prompt written in the style of the Scholastic Aptitude Test (SAT). The prompt and instructions are provided in the Appendix.

3.2.2.2. Writing score

Writing ability was assessed using expert human scores. Two expert human raters scored each essay independently using a 6-point rating scale developed for the SAT. The rating scale was used to holistically assess the quality of the essays and had a minimum score of 1 and a maximum score of 6. Raters were first trained to use the rubric with a small sample of similar essays. A Cronbach's Alpha (α) was used to assess inter-rater reliability between raters. When the raters reached an $\alpha = .70$, the ratings were considered reliable and the raters scored a larger subsection of the corpus. The final inter-rater reliability for the raters for the essays was $\alpha > .89$. Raters were then given the opportunity to adjudicate any ratings wherein the disagreement between the raters was greater than one. After adjudication, exact accuracy between raters was 67% and adjacent accuracy was 100%. Average scores between the raters were calculated for each essay to provide a holistic score.

3.2.3. Reading Comprehension Ability

Reading comprehension ability was assessed with the Gates-MacGinitie (4^{th} ed.) reading skill test (form S) level 10/12 (MacGinitie & MacGinitie, 1989). The comprehension test comprises 48 multiple-choice questions that assess students' reading comprehension ability across short passages. Each passage is associated with two to six questions. The questions assess shallow text comprehension as well as deeper level comprehension that require the reader to make inferences about the text. The participants were administered the standard instructions, including two practice questions, and given 20 minutes to complete the test.

3.2.4. Vocabulary Knowledge

The vocabulary section of the Gates-MacGinitie (4^{th} ed.) reading test (form S) level 10/12 (MacGinitie & MacGinitie, 1989) was used to assess the participants' vocabulary knowledge. The test is comprised of 45 simple sentences, each with an underlined vocabulary word. For each underlined word, participants are asked

to select the most closely related word from a list of five choices. The sentences are designed to suggest the vocabulary word's part of speech but provide no contextual information about the word's meaning. Participants were administered the standard instructions, including two practice questions, and given 10 minutes to complete the test.

3.2.5. Working Memory Capacity

Participants completed the Automated Operation Span (Aospan; Unsworth, Heitz, Schrock, & Engle, 2005) task to provide a measure of their working memory capacity. We chose to use this non-verbal, mathematics-based version of the complex span task to ensure that any variance that was shared between working memory scores and the other measures was due to an executive control component, rather than verbal or reading comprehension-related skills. In this task, participants are asked to remember a series of letters while performing simple math problems. In each trial, participants view an equation on the computer screen and are instructed to press a button after solving the equation. Participants are then presented with a potential solution and asked to judge its accuracy. Feedback is presented to the participants and a random letter then appears to be recalled at a later time. After a solving a set of three to seven math equations, participants are presented with 12 letters and asked to select the letters they recognize in the correct order. Feedback on both math and letter recall accuracy is then presented to the participants. Participants are asked to maintain their equation accuracy at approximately 85% throughout the task. The Aospan task required approximately 15-20 minutes to complete and concluded after 75 trials. A participant's Aospan Total reflected the total number of letters correctly recognized and correctly ordered.

3.2.6. Component Processes Task

Participants completed Hannon and Daneman's (2001) component processes task, which is intended to measure individual differences in four cognitive component processes of reading comprehension: the ability to access prior knowledge from long-term memory, to integrate accessed prior knowledge with new text information, to make inferences based on information provided in the text, and to recall the new text information from memory.

The participants are explicitly instructed to use their world knowledge throughout the task. The task consists of six three-sentence paragraphs, each accompanied by 18 true-false statements. The sentences in the paragraphs are variably composed of nonsense terms (e.g., MIRT, COFT) and real terms (e.g., WATERMELON, OSTRICH). Each sentence links two terms together using two to four comparative features (e.g. A MIRT resembles an OSTRICH but is larger and has a longer neck.). Overall, each paragraph comprises three nonsense terms, two real terms, and two to four semantic features. An example paragraph is provided below:

A MIRT resembles an OSTRICH but is larger and has a longer neck.
A COFT resembles a ROBIN but is smaller and has a longer neck.
A FLIP resembles a COFT but is smaller, has a longer neck, and nests on land.

For each trial, participants are asked to study the sentences one at a time as they appear on the screen. After each paragraph, participants are asked true or false statements about the information provided in the sentences. Each true or false statement is one of four types: text memory statements, text inferencing statements, knowledge access statements, and knowledge integration statements. Accuracy is measured as the percentage of correct responses for each overall statement type (text memory, text inferencing, knowledge access, and knowledge integration).

Text memory statements assess information that is explicitly mentioned in the paragraph without calling upon the use of outside world knowledge (e.g. A MIRT is larger than an OSTRICH). Text inferencing statements assess inferences about information provided explicitly in the paragraph without the use of world knowledge (e.g. A FLIP has a larger neck than a ROBIN). Knowledge access statements assess participants' ability to access prior world knowledge but require no information presented in the paragraph (e.g. A BLUEJAY lives in Canada, whereas an OSTRICH typically doesn't). Knowledge access statements are divided into two types: low and high. Low-knowledge access statements test access to a fact that is not explicitly presented in the paragraph, but included two real terms and a feature included in the given paragraph (e.g., An OSTRICH has a longer neck than a ROBIN). High-knowledge access statements also include two real terms and test access to a fact that is not presented in the paragraph (e.g., A ROBIN lives in Canada, whereas a PENGUIN typically doesn't). However, they only include one real term presented in the paragraph. The other real term and the semantic feature are not presented in the paragraph. Finally, knowledge integration statements assess participants' ability to integrate prior world knowledge with the information provided in the paragraphs (e.g. A PENGUIN is larger than a COFT). Knowledge integration statements are divided into three types that increase in difficulty level: low, medium, and high. Low-knowledge integration statements include one nonsense term, one real term, and a semantic feature, all of which are presented in the paragraph (e.g., A MIRT has a longer neck than a ROBIN). In the medium-knowledge integration statements, the nonsense term and the semantic feature are presented in the paragraph, but the real term is not (e.g., A MIRT is larger than a BLUEJAY). Finally, the high-knowledge integration statements contain a nonsense term that is in the paragraph, but also contain a real term and a semantic feature that are not presented in the paragraph (e.g., Like PENGUINS, MIRTS can't fly).

3.3. Procedure

The study comprised one laboratory session that lasted approximately 2 hours. The duration and order of these tasks are as follows; a demographics questionnaire (approximately 5 minutes), timed-essay (approximately 25 minutes), vocabulary

test (approximately 10 minutes), and reading comprehension test (approximately 20 minutes), component processes task (approximately 30) and Aospan task (approximately 20 minutes). The Aospan and components processes tasks were presented using E-Prime software (Psychology Software Tools, Pittsburgh, PA), all other measure were presented using an online survey. In the case of the persuasive essay task, participants were not allowed to proceed before the 25 minutes had elapsed. However, for all other tasks, participants moved on to the subsequent task as soon as they had completed the task. For the Gates-MacGinitie vocabulary and comprehension tests, the maximum time allowed to complete the tasks was 10 and 20 minutes, respectively.

4. RESULTS

Correlation and regression analyses were conducted to examine the relations among students' reading comprehension scores, writing scores, and the six individual difference measures (i.e., vocabulary knowledge, working memory capacity, and the four cognitive component processes). We first confirm relations between students' scores on the collected measures and their reading comprehension ability. We then investigate how and whether students' scores on these measures were correlated with, and predictive of, their performance on a persuasive essay writing task.

4.1. Descriptive and Correlation Analyses

Table 1 presents the means, standard deviations, and ranges for students' scores on the collected measures (i.e., Gates-MacGinitie Reading Comprehension Test, Persuasive Essay, Gates-MacGinitie Vocabulary Test, Component Processes Task, and AOSPAN Task), as well as the Pearson correlations among all of the measures. Multicollinearity between the 6 predictor variables (Component Processing Task, AOSPAN, and vocabulary knowledge) was assessed using a threshold of $r > .90$ (Tabachnick & Fidell, 2001). None of the 6 variables demonstrated multicollinearity, therefore, none were removed from the current analyses. It is important to note, however, that some of the measures were strongly correlated; thus, caution should be exercised when interpreting the results of the analyses. As revealed in Table 1, AOSPAN Total was the only score not significantly correlated with all of the other collected measures. Because students' reading comprehension, writing, vocabulary, and component processes scores all exhibited significant relations, it can be inferred that

Table 1. Descriptive Statistics and Pearson Correlations for Measures Related to Reading and Writing

Variables	1	2	3	4	5	6	7	8	*M*	*SD*	Range
1. Reading Comprehension	1.00								29.40	9.99	10-48
2. Writing Score	.57**	1.00							3.02	1.14	1-6
3. Vocabulary Knowledge	.79**	.55**	1.00						30.89	9.52	6-45
4. *CP*: Text Memory[a]	.55**	.25**	.40**	1.00					64.84	14.35	35.71-97.62
5. *CP*: Text Inferencing[a]	.51*	.25**	.34**	.83**	1.00				61.16	15.24	25.00-88.89
6. *CP*: Knowledge Access[a]	.68**	.41**	.68**	.53**	.39**	1.00			80.33	12.50	46.67-98.33
7. *CP*: Knowledge Integration[a]	.58**	.31**	.51**	.81**	.66**	.71**	1.00		68.45	14.54	43.75-98.96
8. AOSPAN Total	.10	.01	.12	.22*	.14	.14	.20*	1.00	56.44	11.79	23-75

Notes: *CP* = component process; [a] Statistics for the component scores are reported as percentages.
*$p < .05$. ** $p < .001$.

both reading comprehension and writing ability rely on a related set of vocabulary knowledge and higher-level cognitive skills.

Reading comprehension scores were strongly correlated with writing scores at $r = .57$, $p < .001$, yielding a large effect size (see Cohen, 1988), which is in line with previous literature that has reported correlations between reading and writing scores ranging from $r = .20$ to $r = .50$ (Fitzgerald & Shanahan, 2000). The moderate to strong correlation typically found between reading and writing suggests that the two processes share some degree of commonality; however, because perfect correlations have not been reported between the two, this also implies that they are separable constructs and potentially exhibit unique relations with the collected measures.

4.1.1. Reading Comprehension

Consistent with previous research, students' performance on the reading comprehension test was most strongly related to their vocabulary knowledge (Perfetti, 1985). In other words, the successful comprehension of texts was more difficult for students who possessed less explicit knowledge of the words in a given text. In addition to vocabulary knowledge, participants' ability to comprehend passages was related to

several higher-level cognitive abilities, providing confirmatory evidence for their role in the comprehension process.

The components most highly related to reading comprehension scores were the ability to access prior knowledge from long-term memory and the ability to integrate this knowledge with new information. Thus, in addition to the need for explicit word knowledge, comprehension also depended on students' ability to access and integrate this prior knowledge with new information. In addition, reading comprehension was significantly related to the remaining two component scores: drawing text-based inferences based on a text and recall of information explicitly presented in the text. Therefore, aside from the ability to access and integrate prior knowledge, the ability to remember, understand, and make deductions based on a given text was strongly related to students' scores on reading comprehension tests. AOSPAN was the only variable that was not significantly related to reading comprehension scores, suggesting that variations in the students working memory capacity were not driving differences in their ability to comprehend texts. Overall, the results suggest that prior knowledge and the higher-level cognitive skills associated with the use of this knowledge are strongly related to reading comprehension proficiency.

4.1.2. Writing Proficiency

Correlations were calculated between the collected measures and students' essay scores. Results from these analyses indicate that the writing process shares some knowledge sources and higher-level cognitive abilities associated with reading comprehension performance.

The correlations indicate that students' essay scores were most strongly related to their vocabulary knowledge. Thus, similar to reading comprehension, the writing process is largely dependent on word knowledge. Students who knew fewer words on the vocabulary test tended to have greater difficulty producing quality essays. On the other hand, unlike the reading comprehension process, the correlation between vocabulary knowledge and writing was only moderate and, therefore, more weakly related to essay scores than reading comprehension scores.

Second, the remaining measures exhibited correlations comparable, albeit weaker, to those observed with reading comprehension scores. Specifically, the ability to recognize previously viewed information, the ability to make inferences about a given text, the ability to access prior knowledge from memory, and the ability to integrate this knowledge with new information were all significantly correlated with essay scores. Thus, although reading comprehension and writing scores were both related to

vocabulary knowledge and the higher-level cognitive skills, writing scores exhibited much weaker relationships to the measures overall. Finally, and also similar to reading comprehension, was the correlation between essay scores and AOSPAN. In this study, variations in students' working memory scores did not significantly relate to variations in their performance on either the comprehension or essay writing tasks.

Accordingly, it may be the case that reading comprehension and writing are similar cognitive processes, but the writing process is more reliant on additional, knowledge sources and higher-level cognitive abilities (which were not assessed in this study). Overall, the results of the correlation analyses suggest that the higher-level cognitive skills related to the reading comprehension process may play a similar role in the writing process, albeit a somewhat weaker one.

4.2. Regression Analyses

4.2.1. Reading Comprehension

To determine whether the higher-level cognitive skills were predictive of students' reading comprehension performance, a linear regression analysis was conducted to predict reading comprehension from the four component processes scores. This analysis yielded a significant model F (4, 101) = 28.06, $p < .001$; $R^2 = .53$,[1] with two significant predictors: text inferencing and knowledge access (see Table 2). Results of this analysis suggest that students' performance on the reading comprehension assessment was strongly influenced by their ability to make inferences about the text and their ability to access prior knowledge about the given topics.

A follow-up hierarchical linear regression analysis was conducted to assess whether the component scores accounted for unique variance in students' reading comprehension scores over and above vocabulary knowledge. Therefore, vocabulary knowledge was entered as the first block of a regression analysis and the four component scores were entered into a second block. This analysis yielded two significant models. The first model confirmed that vocabulary knowledge significantly predicted reading comprehension scores, F (1, 99) = 169.43, $p < .001$; $R^2 = .63$ (see Table 3). Further, the second model revealed that the component scores accounted for significant variance above and beyond the variance accounted for in the first block, F (5, 95) = 47.25, $p < .001$; $R^2 = .71$. One

[1] Note that a portion of the variance in the final R^2 for all of the regression analyses is explained by non-significant variables.

Table 2. Linear Regression Analysis for Component Processes Predicting Reading Comprehension Scores and Writing Scores

	Reading Comprehension Scores				Writing Scores			
Variable	**B**	**SE B**	**B**	**t**	**B**	**SE B**	**B**	**t**
Constant	−18.58	4.66		−3.99**	−.22	.70		−.31
CP: Text Memory	.05	.11	.07	.44	−.01	.02	−.10	−.51
CP: Text Inferencing	.17	.08	.26	2.08*	.02	.01	.20	1.24
CP: Knowledge Access	.46	.08	.58	5.84**	.04	.01	.42	3.26*
CP: Knowledge Integration	−.04	.10	−.05	−.38	−.01	.01	−.05	−.25
		$R^2 = .53$				$R^2 = .19$		

Notes: *CP* = component process; * $p < .05$. ** $p < .001$.

of the component scores was significant (knowledge access) and another was marginally significant (text inferencing). The results of this regression analysis suggest that the ability to comprehend text is strongly predicted by students' word knowledge, as well as higher-level cognitive skills associated with the access of prior knowledge and the generation of inferences.

Table 3. Linear Regression Analysis for Measures Predicting Reading Comprehension Scores and Writing Scores

		Reading Comprehension Scores				Writing Scores			
Model	**Variable**	**B**	**SE B**	***B***	**ΔR**	**B**	**SE B**	***B***	**ΔR**
Model 1					.63**				.30**
	Vocabulary Knowledge	.07	.01	.55**		.07	.01	.55**	
Model 2					.08**				.01
	Vocabulary Knowledge	.62	.08	.59**		.06	.01	.48**	
	CP: Text Memory	.10	.10	.12		−.01	.02	−0.6	−.30
	CP: Text Inferencing	.31	.18	.17		.03	.03	.13	.82
	CP: Knowledge Access	.25	.12	.19*		.02	.02	.10	.72
	CP: Knowledge Integration	−.05	.08	−.06		−.01	.01	−.05	−.31
			$R^2 = .72$				$R^2 = .31$		

Notes: *CP* = *component process*; * $p < .05$. ** $p < .001$.

4.2.2. Writing Proficiency

A linear regression analysis was conducted to determine whether the higher-level component processes were predictive of students' writing scores. As Table 2 reveals, the model was significant, F (4, 101) = 5.72, p < .001; R^2 = .19, with one significant predictor: knowledge access. The results of this analysis indicate that writing performance had one similar predictor as the reading comprehension analysis (i.e., knowledge access). Thus, the reading comprehension and writing processes both rely on a similar cognitive ability to successfully access prior knowledge about a given topic.

A follow-up hierarchical regression analysis was conducted to examine the degree to which the component scores could predict essay scores over and above vocabulary knowledge. Writing scores were regressed onto vocabulary knowledge in a first block, yielding a significant model, F (1, 99) = 42.37, p < .001; R^2 = .30 (see Table 3). The four component scores were then entered into the second block of the model. This yielded a significant model, F (5, 95) = 8.48, p < .001; however, the block did not provide significant unique variance above the first block. Overall, the results of this analysis suggest that, although all of the collected measures were correlated with writing proficiency, students' writing performance was most strongly predicted by their vocabulary knowledge.

Overall, the results of the regression analyses confirm the correlation analyses indicating that both reading comprehension and writing were strongly predicted by vocabulary knowledge. The regression analyses also suggest that, aside from knowledge access, individuals' higher-level cognitive abilities accounted for little additional variance over vocabulary knowledge. Therefore, despite the significant correlations between these collected measures and reading comprehension and writing scores, only vocabulary knowledge predicted significant, unique variance in both skills.

5. DISCUSSION

In this study, we examined whether students' reading comprehension and writing scores were similarly or differently related to lower- and higher-level cognitive skills. The results of the current study indicate that reading comprehension proficiency was strongly related to both vocabulary knowledge and the higher-level cognitive skills. Further, writing ability was moderately associated with a subset of the measured variables, namely vocabulary knowledge and the ability to access prior knowledge (although

this did not predict unique variance above the vocabulary scores). The only individual difference measure that was not significantly correlated with either reading comprehension or writing ability was working memory capacity. This was likely due to the working memory measure that was used in this study (i.e., a non-verbal or reading-comprehension related measure). Therefore, it may be the case that working memory capacity is largely unrelated to reading comprehension and writing ability, at least with normal, adult populations. However, future research is needed to make strong claims regarding these relationships. Overall, our results support the hypothesis that reading comprehension and writing ability share common knowledge sources and higher-level cognitive skills. However, they also suggest that the writing process is much less reliant on these measured variables than reading comprehension; therefore, the writing process may depend on additional, unmeasured factors, such as writing strategies, writing genres, and grammar.

A valuable contribution of this study is the explicit comparison of reading comprehension and writing performance in terms of higher-level cognitive skills. Although these cognitive constructs have been thoroughly examined in the reading comprehension literature, far fewer studies have focused on how they may overlap with students' writing proficiency. Because of this dearth of cognitive studies related to writing proficiency, relatively little is known about the higher-level cognitive skills that students employ when they engage in the *process* of text production. As mentioned earlier in this paper, most contemporary cognitive models of the writing process focus on the role of lower-level cognitive skills in their examination of text production. However, the current study revealed that working memory (our measure of lower-level cognitive skills) was unrelated to either reading comprehension or writing scores. This result supports the argument that researchers should place a stronger emphasis on the investigation of higher-level cognitive skills when studying and developing models of the text comprehension and production processes. Additionally, such studies can help researchers develop more sophisticated conceptualizations of how text comprehension and production overlap, which can inform theoretical models of literacy more generally. The results of this study also provide crucial information that may inform effective pedagogical practices aimed at improving literacy performance. We hypothesize that the shared components identified between the reading comprehension and writing processes can be leveraged to provide more beneficial interventions for struggling students.

5.1. Reading-Writing Connections

The results of this study confirm a strong link between the reading comprehension and writing processes (i.e., scores on these measures were correlated at $r = .57$) and identify higher-level cognitive skills that are shared between the two literacy activities. Correlation and regression analyses confirmed that the four cognitive component processes were strongly predictive of reading comprehension scores, accounting for over half of the variance. However, only knowledge access (and marginally, text inferencing) accounted for significant variance over and above vocabulary knowledge. These results support the notion that reading comprehension relies on both prior word knowledge and higher-level cognitive processes. While vocabulary knowledge was most highly related to reading comprehension scores, the ability to comprehend text was additionally influenced by higher-level cognitive skills, such as the ability to access prior knowledge and make inferences about a given text. Overall, these analyses confirm prior literature suggesting that successful text comprehension is largely influenced by an individual's degree of word knowledge, prior knowledge, and their ability to make inferences about a text. Future studies will need to further tease apart these relations by examining differential relations between the individual difference measures and literal and inference-generation questions on reading comprehension assessments. Such analyses will provide more fine-grained information about the role of lower- and higher-level cognitive skills on students' text comprehension.

Beyond our analysis of reading comprehension scores, we further investigated the degree to which the higher-level cognitive skills similarly or differentially impacted writing performance. The results revealed that some of the higher-level cognitive skills that were related to reading comprehension performance were also related to students' writing ability. Specifically, the correlation analysis revealed that writing performance was significantly related to all four of the component processes (i.e., text memory, text inferencing, knowledge access, and knowledge integration). In an initial regression analysis, however, knowledge access was the only component process that significantly predicted writing performance, and this significance was washed out once vocabulary knowledge was added to the model. Importantly, these results provide insight into the cognitive and knowledge factors related to the writing process. Additionally, they suggest that variation in students' performance on writing assessments may be largely attributed to individual differences in their vocabulary knowledge and, to a lesser extent, in their ability to successfully activate relevant prior knowledge. Overall, the results of the current study fall in line with previous

research, suggesting that vocabulary knowledge was strongly related to both the ability to comprehend and produce text (e.g., Abbott & Berninger, 1993; Fitzgerald & Shanahan, 2001). However, they also suggest that the two literacy tasks are related to higher-level cognitive skills associated with the use of this knowledge.

A limitation of the current study relates to the assessments used to measure both reading comprehension and vocabulary knowledge. First, there currently exists some debate as to whether the Gates-MacGinitie Reading Test accurately evaluates the cognitive skills (specifically related to inferencing) that are required for deep comprehension (Cutting & Scarborough, 2006; van den Broek & Espin, 2012). Therefore, it is possible that the relations between the scores on the component processes task (i.e., those related to higher-level cognitive skills) and the reading comprehension task would be much higher if we were to have used a more sophisticated measure of deep comprehension. Future studies should consider the limitations of the Gates-MacGinitie reading test when investigating comprehension—particular when assessing the higher-level processes that are related to comprehension. Additionally, although both the reading comprehension and vocabulary assessments were technically separate measures, they were developed as subscales of a holistic measure of reading skill (i.e., there are comprehension and vocabulary sections of the test). While the vocabulary test did not involve comprehension of long passages, the task itself did require students to read simple phrases and sentences. Therefore, it is not a *pure* measure of vocabulary. It is therefore likely that the relations between vocabulary knowledge and the reading comprehension and writing tasks were slightly inflated. To address these issues, future studies should utilize multiple assessments of both reading comprehension and writing. This will reduce variance attributed to test-level effects and allow researchers to draw stronger conclusions about the relations between higher-level skills and reading comprehension and writing. Despite this limitation, however, the results suggest that both reading and writing are similarly related to sources of vocabulary knowledge and the four measured component processes; yet, writing is drawing on other areas of knowledge or processes that were not measured in the current study.

5.2. Implications for the Classroom

The results of the current study have important implications for the development of effective literacy pedagogy. First, these findings indicate

that word knowledge is critical for the successful completion of both reading comprehension and writing tasks. Therefore, as the depth of students' vocabulary knowledge increases, their performance on both reading comprehension and writing tasks increases as well. In terms of pedagogy, this result suggests that teachers should consider placing a strong emphasis on vocabulary instruction in the classroom. Unfortunately, vocabulary interventions tend to have limited success (Elleman, Lindo, Morphy, & Compton, 2009; Mol, Bus, & deJong, 2009; Pearson, Hiebert, & Kamil, 2007). Many vocabulary instruction studies have shown improvements in students' decoding ability and in their ability to derive word meanings from context; however, they rarely reveal improvements in students' reading or writing ability (Baumann, Edwards, Boland, Olejnik, & Kame'enui, 2003; Elleman et al., 2009; Mol et al., 2009; Pearson et al., 2007). These results, combined with those reported here, imply that a more successful approach may be to provide vocabulary instruction in the context of the targeted skill, such as reading comprehension or writing. The current findings further indicated that reading comprehension and writing performance are both influenced by students' abilities to access their prior knowledge. This implies that it may not be enough to know words or concepts. Students must learn skills and strategies that allow them to access and use their knowledge (McNamara & Scott, 1999; McNamara, 2004).

Although this study provided some significant insights into the processes involved in literacy skills, there are many questions that remain to be answered. First, this study provided little information on the role that development might play on the reading-writing connection. Future studies including multiple age groups will provide valuable information regarding whether the patterns of relations change as students develop their knowledge and cognitive skills. Second, the number of measures that could be included in this study was relatively limited. Studies including a wider range of individual difference measures (e.g., motivation, strategy knowledge, or attention control) will provide a more complete picture of reading comprehension and writing processes and the relations between them. Finally, this study did not tease apart differences between native and non-native speakers of English. Certainly, the reading comprehension and writing processes are different in the first and second languages. Therefore, future work is needed to investigate how language differences influence these literacy processes, as well as what individual differences contribute to proficiency in these skills.

6. CONCLUSION

The results of this study and future studies on this topic have the potential to have a strong influence on the design and implementation of literacy curricula. Although reading comprehension and writing are clearly different tasks, research indicates that they overlap in terms of their purposes, processes, and sources of knowledge. Research investigating the role of cognition in the reading-writing connection, therefore, may provide insight into additional processes and knowledge sources needed to reach proficiency in both reading comprehension and writing. One crucial question to address is whether there are specific cognitive and knowledge-based components of literacy proficiency. To answer this question, research is needed that investigates how multiple factors influence students' proficiency across a variety literacy tasks. If researchers can identify these components of literacy, educators may be able to determine the skills and knowledge sources that should be most strongly emphasized in the classroom, and the appropriate situations to provide reading and writing instruction in combination versus separately.

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APPENDIX

Essay Prompt:

You will now have 25 minutes to write an essay on the prompt below. The essay gives you an opportunity to show how effectively you can develop and express ideas. You should, therefore, take care to develop your point of view, present your ideas logically and clearly, and use language precisely.

While serious thinking about important matters may disturb people in the short term, it benefits them immeasurably in the long term. Only by confronting unpleasant truths and by weighing both sides of complex issues can people understand the facts—whether in history, politics, literature, or their own lives—and make appropriate decisions. People may find it difficult, or uncomfortable, to think seriously about important matters, but not doing so means that they are leading lives without meaning or purpose.

Does every individual have an obligation to think seriously about important matters, even when doing so may be difficult?

Plan and write an essay in which you develop your point of view on this issue. Support your position with reasoning and examples taken from your reading, studies, experience, or observations.